

# CALIFORNIA CURRENT INTEGRATED ECOSYSTEM ASSESSMENT (CCIEA) CALIFORNIA CURRENT ECOSYSTEM STATUS REPORT, 2017

*A report of the NOAA CCIEA Team to the Pacific Fishery Management Council, March 8, 2017.*

*Editors: Dr. Chris Harvey (NWFSC) and Dr. Toby Garfield (SWFSC)*

## 1. INTRODUCTION

Section 1.4 of the 2013 Fishery Ecosystem Plan (FEP) outlines a reporting process wherein NOAA provides the Council with a yearly update on the state of the California Current Ecosystem (CCE), as derived from environmental, biological and socio-economic indicators. NOAA's California Current Integrated Ecosystem Assessment (CCIEA) team is responsible for this report. This marks our 5<sup>th</sup> report, with prior reports in 2012 and 2014-2016.

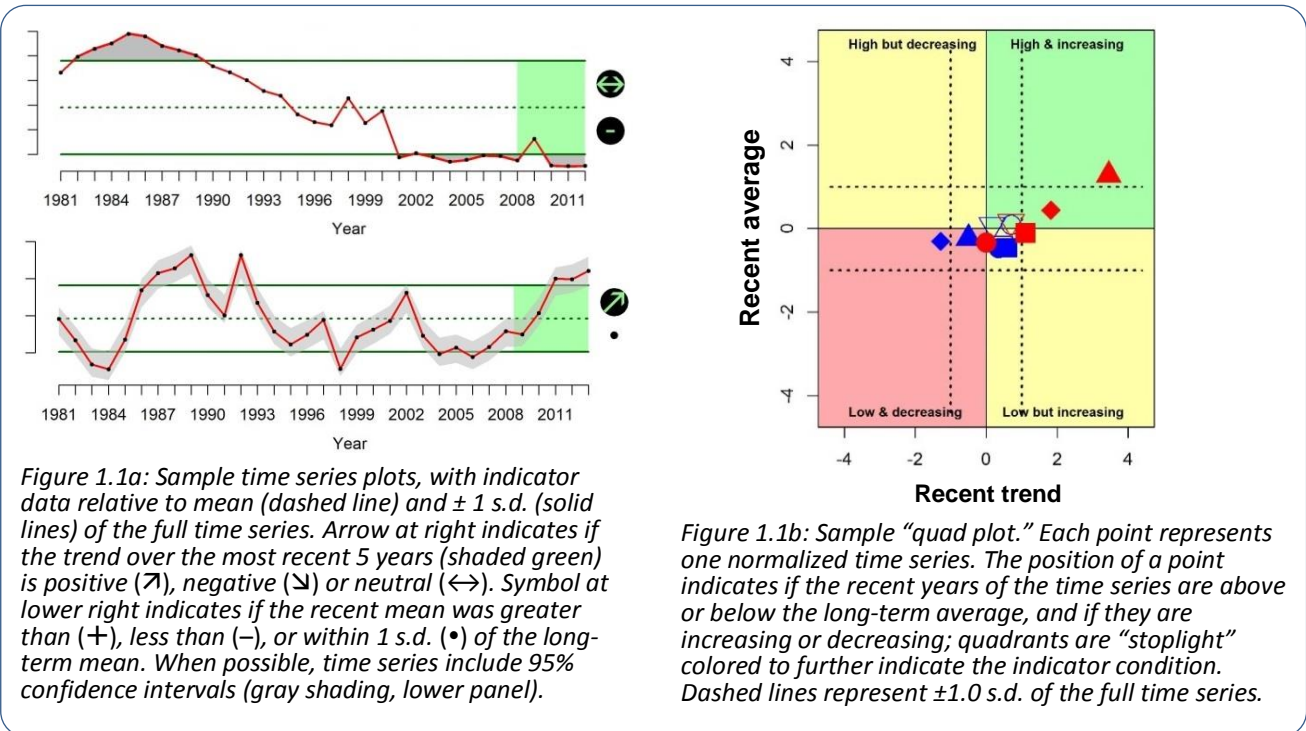
The highlights of this report are summarized in Box 1.1. Sections below provide greater detail. In addition, Supplemental Materials are provided at the end of this document, in response to previous requests from Council members or the Scientific and Statistical Committee (SSC) to provide additional information, or to clarify details found within this short report.

### *Box 1.1: Highlights of this report*

- Following the unprecedented warm anomaly of 2013-2016 and the major El Niño event of 2015-2016, most large-scale climate indices for the Northeast Pacific (ONI, PDO and NPGO) have returned to relatively neutral values.
- Coastal upwelling was relatively weak in the northern California Current throughout 2016; upwelling along the central coast was initially weak but strengthened by summer, while upwelling on southern coast was average to above-average.
- Snowpack rebounded from the extremely low 2015, although much of the 2016 snow melted rapidly, leading to low streamflows; so far, 2017 precipitation is well above average.
- Copepod biomass off Newport, OR remains dominated by relatively energy-poor species as of fall 2016.
- The spring/summer pelagic forage community was once again highly diverse in 2016. Surveys experienced poor catches of sardine, market squid and krill. However, surveys had high but patchy catches of juvenile rockfish, juvenile hake and anchovy.
- Chinook salmon escapements through 2014-2015 varied by region and life history type. We remain concerned about environmental conditions for Chinook and coho salmon that went to sea over the past several years.
- California sea lions at the San Miguel Island colony experienced very poor foraging conditions to support pups in the 2015 cohort, though preliminary evidence suggests better conditions for the 2016 pups.
- Commercial fishing landings and revenues declined markedly in 2015, driven mainly by drops in harvest of Pacific hake, coastal pelagic species, and crabs.

## 1.1 NOTES ON INTERPRETING TIME SERIES FIGURES

Throughout this report, most time series figures follow common formats, illustrated in Figure 1.1; see captions for details. In coming years we will include model fits to time series data, derived from Multivariate Auto-Regressive State Space (MARSS) models as recommended by the SSC Ecosystem Subcommittee (SSCES; see advisory body reports, Agenda Item E.1.b., March 2015).



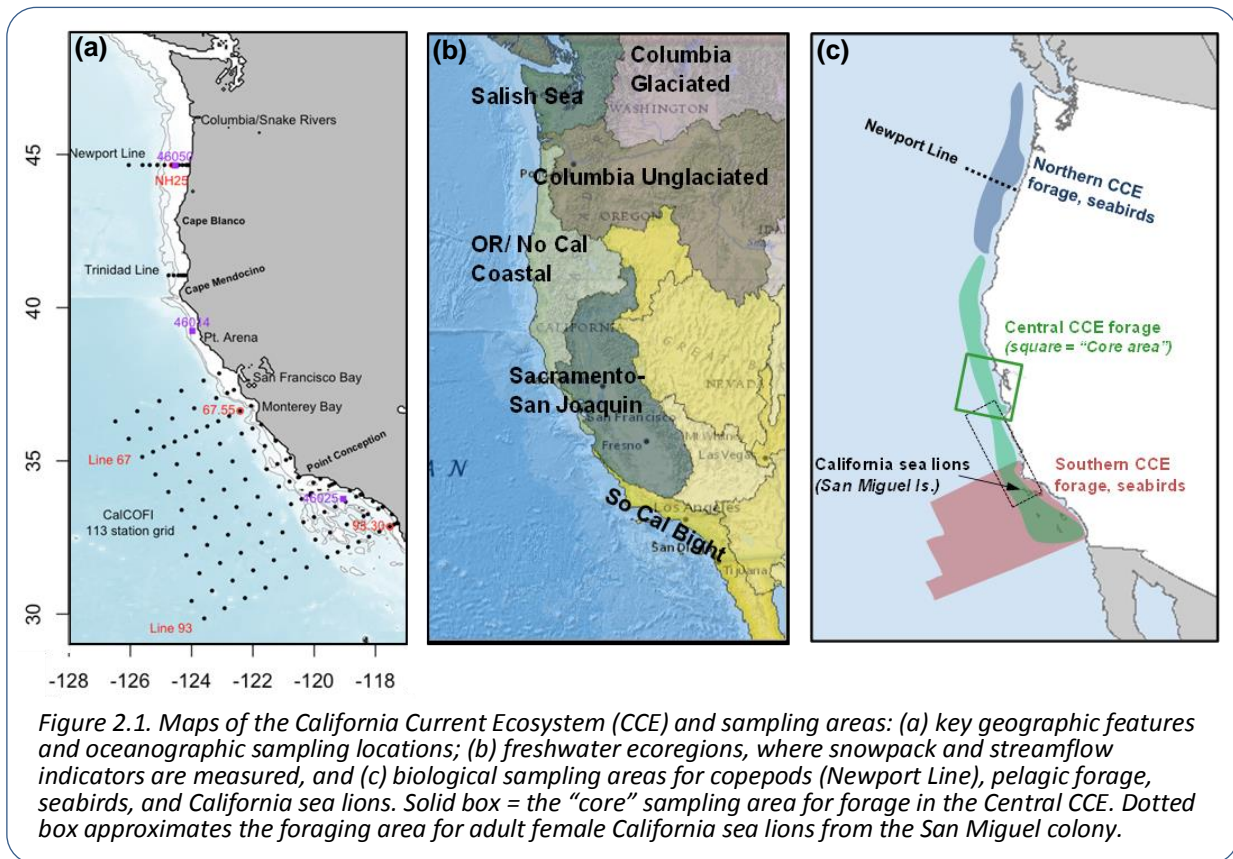
## 2. SAMPLING LOCATIONS

Figure 2.1a shows the CCE and major headlands that demarcate key biogeographic boundaries, in particular Cape Mendocino and Point Conception. We generally consider the region north of Cape Mendocino to be the “Northern CCE,” the region between Cape Mendocino and Point Conception the “Central CCE,” and the region south of Point Conception the “Southern CCE.”

Figure 2.1a also shows sampling locations for much of the regional climate and oceanographic data (Section 3.2) presented in this report. In particular, much of our physical and chemical oceanographic data are collected on the Newport Line off Oregon and the CalCOFI grid off California. Physical oceanography sampling is further complemented by basin-scale observations and models.

Freshwater habitats worldwide can be spatially grouped into “ecoregions,” according to the designations of Abell et al. (2008) (see also [www.feow.org](http://www.feow.org)). The freshwater ecoregions in the CCE are shown in Figure 2.1b, and are the basis by which we summarize freshwater habitat indicators relating to streamflow and snowpack (Section 3.4).

The map in Figure 2.1c represents sampling for most biological indicators, including copepods (Section 4.1), forage species (Section 4.2), California sea lions (Section 4.5) and seabirds (Section 4.6). Not shown is groundfish bottom trawl sampling (see Section 4.4), which covers most trawlable habitat on the shelf and upper slope (55–1280 m depths) in US waters; the blue and green polygons in Figure 2.1c roughly approximate the areal extent of the bottom trawl survey.



### 3. CLIMATE AND OCEAN DRIVERS

The Northeast Pacific has experienced exceptional climate variability since 2013, reaching new extremes for many indicators. After a series of events that caused unprecedented warming in the CCE, conditions have changed since the summer of 2016 into the winter of 2016-2017, producing cooler coastal waters and a succession of winter storms with high precipitation. The strong El Niño event peaked in the tropical Pacific in the winter of 2015-2016, but its influence on the CCE was different than strong El Niño events of 1982-1983 and 1997-1998. Sea surface temperatures were exceptionally high, but the extent of heating into the water column was less than in past El Niño events (Fig. 3.1). Late winter upwelling was not as weak, and upwelling was much stronger leading into the spring.

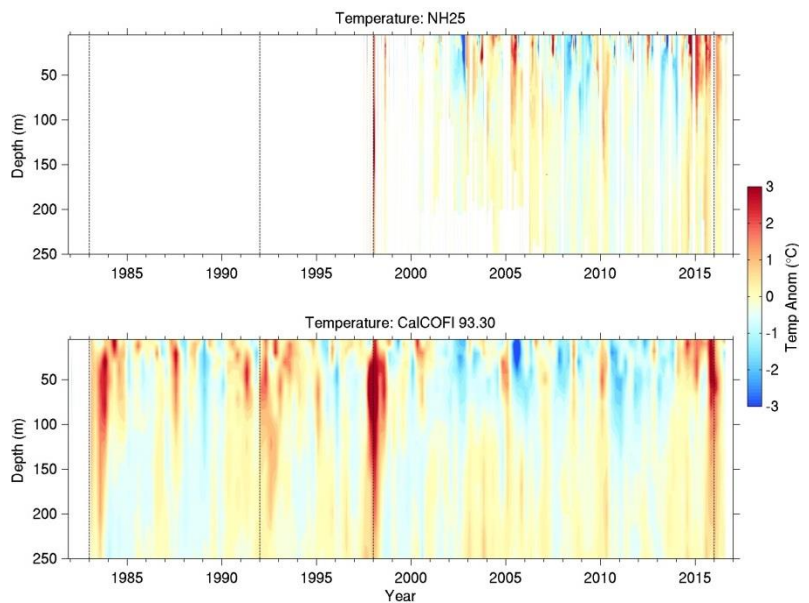


Figure 3.1. Time-depth temperature contours from nearshore stations NH25 and CalCOFI 93.30 (see Fig. 2.1a). Vertical lines mark El Niño events (1983, 1992, 1998, 2016). Anomalies in winter/spring of 2016 are less extreme at depth than prior major El Niño events.

### 3.1 BASIN-SCALE INDICATORS

The CCE is driven by atmosphere-ocean energy exchange that occurs on many temporal and spatial scales. To capture large-scale variability, the CCIEA team tracks three indices: the status of the equatorial El Niño Southern Oscillation (ENSO), described by the Oceanic Niño Index (ONI)<sup>1</sup>; the Pacific Decadal Oscillation (PDO); and the North Pacific Gyre Oscillation (NPGO). ENSO events impact the CCE by modifying the jet stream and storm tracks, deepening the nearshore thermocline, and generating coastal currents that enhance poleward transport of equatorial and subequatorial waters (and species). A positive ONI indicates El Niño conditions, which usually means more storms to the south, weaker upwelling, and lower primary productivity in the CCE. A negative ONI means La Niña conditions, which usually lead to higher productivity. The PDO is derived from sea surface temperature anomalies (SSTa) in the Northeast Pacific, which often persist in “regimes” that last for many years. In positive PDO regimes, coastal SSTa in the Gulf of Alaska and the CCE tend to be warmer, while those in the North Pacific Subtropical Gyre tend to be cooler. Positive PDOs are associated with lower productivity in the CCE. The NPGO is a low-frequency variation of sea surface height, indicating variations in the circulation of the North Pacific Subtropical Gyre and Alaskan Gyre, which in turn relate to the source waters for the CCE. Positive NPGO values are associated with increased equatorward flow, along with increased surface salinities, nutrients, and chlorophyll-*a*. Negative NPGO values are associated with decreases in such values, implying less subarctic source waters and generally lower productivity.

In summary the general trends are that positive MEI and PDO values and negative NPGO values usually denote conditions that lead to low CCE productivity and negative MEI and PDO values and positive NPGO values are associated with periods of high CCE productivity. These indices vary independently and so there is a wide range of observed variability in the CCE.

#### 3.1.1 BASIN-SCALE PROCESSES, 2014-2016

This past year saw the ONI shift from El Niño to neutral and even La Niña conditions, the PDO switch from strongly positive to neutral, and the NPGO move from strongly negative to neutral (Fig. 3.1.1). Each of these indices would suggest a return to conditions of higher productivity. However, the Northeast Pacific and the CCE still show the after effects of the very anomalous conditions experienced during 2013-2016. The large marine heat wave, a.k.a. “the Blob” (Bond et al. 2015) dissipated in fall of 2016 in the Northeast Pacific, but anomalously

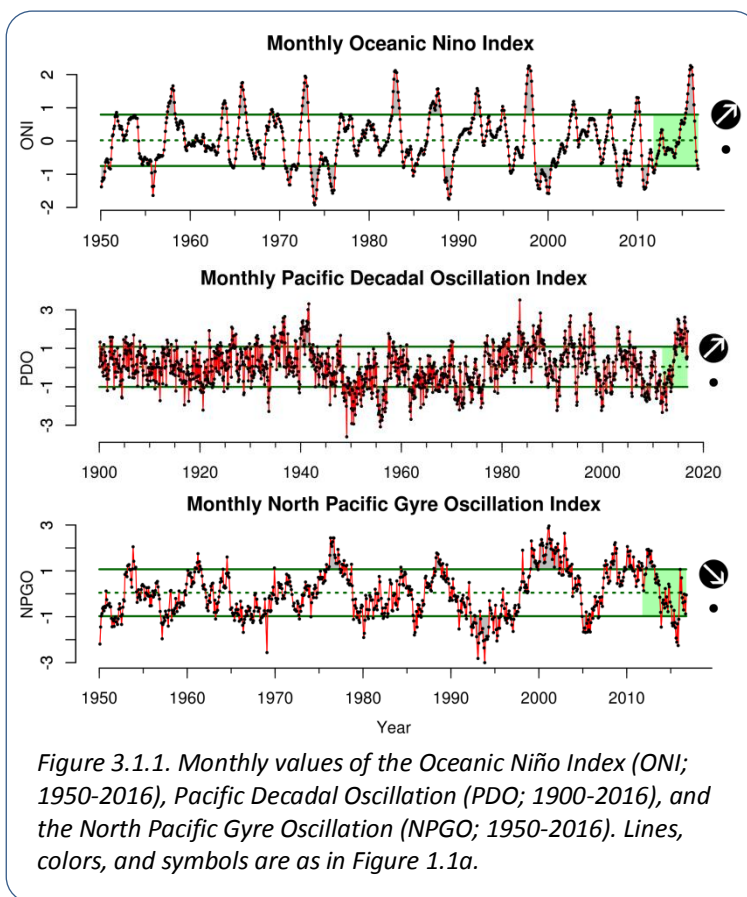
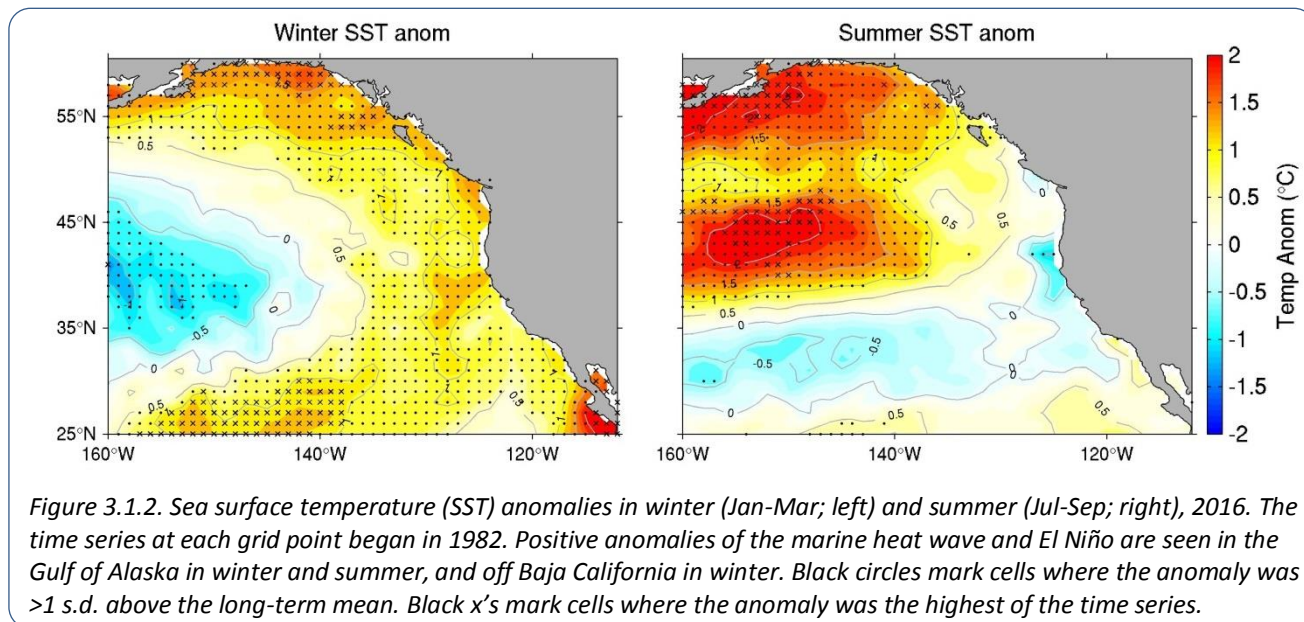


Figure 3.1.1. Monthly values of the Oceanic Niño Index (ONI; 1950-2016), Pacific Decadal Oscillation (PDO; 1900-2016), and the North Pacific Gyre Oscillation (NPGO; 1950-2016). Lines, colors, and symbols are as in Figure 1.1a.

<sup>1</sup>In previous reports, the reported El Niño Index was the Multivariate El Niño Oscillation Index (MEI). The numerical and trend values for ONI and MEI are very similar, and ONI is the index supported by the NOAA Climate Prediction Center. The CCIEA report adopts the ONI as the recommended index.

warm surface waters were present in the Gulf of Alaska and immediately along the North American west coast during the winter (Fig. 3.1.2). Summer SSTa showed no lasting influence of the El Niño event, with anomalies average to slightly below average along the coast from Vancouver to San Diego. Subsurface waters, measured by ARGO floats, in the Northeast Pacific are still warm, with anomalies  $>1^{\circ}\text{C}$  down to 160 m and  $>0.5^{\circ}\text{C}$  down to below 200 m (Appendix E, Fig. E.6). This deep warming is interpreted as a remnant effect of the marine heat wave.



Another marine heat wave formed off Baja California in 2014 and strengthened in 2015, keeping nearshore SSTs  $>0.5^{\circ}\text{C}$  above normal. This event was likely caused by weaker atmospheric forcing in the Southern California Bight and along the Mexican coast (Leising et al. 2015, McClatchie et al. 2016). By summer 2016, SSTs of this region dropped to near average values (Fig. 3.1.2).

In summary, while the 2015-2016 El Niño was one of the largest recorded in terms of equatorial warming and the ONI, the large-scale environmental response of the CCE was dominated in the north by the lingering impacts of the marine heat wave, with only moderate influence from the El Niño, whereas in the south, the CCE was more strongly influenced by the El Niño. Thorough summaries of these dynamics are in Leising et al. (2015) and McClatchie et al. (2016). These large-scale forces will help explain the dynamics of biological indicators in Section 4 below.

### 3.2 REGIONAL CLIMATE INDICATORS

Seasonal high pressure over the Gulf of Alaska and low pressure over the US Southwest drive the upwelling-favorable winds that fuel the high spring-summer productivity of the CCE. Upwelling is a physical process of moving cold, nutrient-rich water from deep in the ocean up to the surface and is forced by strong northerly alongshore winds. Upwelling is critically important to productivity and ecosystem health in the CCE, as it is local coastal upwelling that allows the primary production at the base of the food web. The most common metric of upwelling is the Bakun Upwelling Index (UI), which is a measure of the magnitude of upwelling anywhere along the coast. The timing, strength, and duration of upwelling in the CCE are highly variable by region and by year. The cumulative upwelling index (CUI) is one way to display this variability. The CUI provides an estimate of the net influence of upwelling on ecosystem structure and productivity over the course of the year. The CUI integrates the onset date of upwelling favorable winds ("spring transition"), a general indication of the strength of upwelling, relaxation events and the end of the upwelling season.

### 3.2.1 REGIONAL-SCALE PROCESSES, 2012-2016

Upwelling strength displayed significant regional variability during 2016, with the least favorable conditions in the northern CCE (Appendix E, Fig. E.7). At 45° N, strong downwelling from January through March was followed by average upwelling from April to July; CUI at this latitude was much lower than the strong upwelling of 2015 (Fig. 3.2.1), and similar to the reduced upwelling of the 1998 El Niño event (McClatchie et al. 2016). At 39° N, the spring transition to upwelling began weakly in mid-March and strengthened in May, leading to above-average upwelling by July and comparable CUI to 2015 by August. In the Southern California Bight (~33° N), the CUI was close to the long term mean during the beginning of the season, and above average after June. This is in stark contrast to the reduced upwelling seen throughout the year in 1998 following that comparably large El Niño.

Although CUI was stronger in the south than the north in 2016, productivity did not increase concomitantly as one might expect. This is likely because of increased stratification and a deeper thermocline in this region, due to the lingering effects of the marine heat wave, plus the influence of the 2015-2016 El Niño event (McClatchie et al. 2016).

### 3.3 HYPOXIA AND OCEAN ACIDIFICATION

Nearshore dissolved oxygen (DO) levels and ocean acidification (OA) are related to the strength of coastal upwelling. DO is required for organismal respiration, and DO levels are dependent on a number of physical and biological processes, including circulation, air-sea exchange, and community-level production and respiration. Waters with DO levels below 1.4 ml L<sup>-1</sup> (2 mg L<sup>-1</sup>) are considered to be hypoxic. Low DO can compress habitat and cause stress or even die-offs for sensitive species. OA is caused by increased levels of anthropogenic CO<sub>2</sub> in seawater, which impacts the chemical environment of marine organisms by reducing both pH and carbonate ion concentrations. A key indicator of OA effects is aragonite saturation state, a measure of how corrosive seawater is to organisms with shells made of aragonite (a form of calcium carbonate). Values <1.0 indicate corrosive conditions that have been shown to be stressful for many CCE species, including oysters, crabs, and pteropods. Upwelling, which drives primary production in the CCE, also transports hypoxic, acidified waters onto continental shelves, where increased

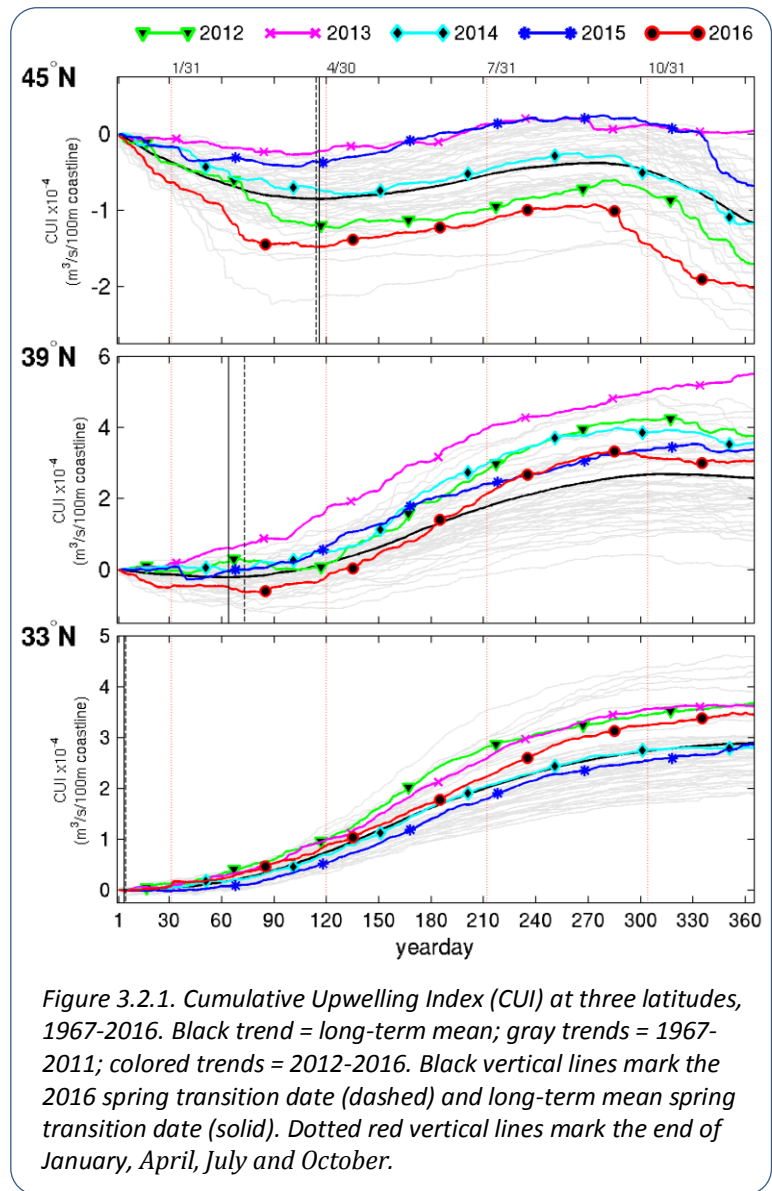


Figure 3.2.1. Cumulative Upwelling Index (CUI) at three latitudes, 1967-2016. Black trend = long-term mean; gray trends = 1967-2011; colored trends = 2012-2016. Black vertical lines mark the 2016 spring transition date (dashed) and long-term mean spring transition date (solid). Dotted red vertical lines mark the end of January, April, July and October.

community-level respiration can further reduce water column DO and exacerbate OA (Chan et al. 2008, Feely et al. 2008).

At the three stations shown here, DO was seasonally variable, with peaks in the winter, but all measurements were consistently above the hypoxia threshold of 1.4 ml/L in 2016 (Fig. 3.3.1). The 5-year annual trend at each site has been stable, but there is evidence of seasonal increases in DO; seasonal time series are presented in Appendix E.3 of the Supplement. Briefly: station NH25 off Oregon has experienced increasing winter DO over the past 5 years. At the nearshore station 93.90 off Southern California, DO has declined since 1984, driven mainly by winter values, and was ~1 s.d. below the mean in winter 2016. However, the recent trend is stable and possibly increasing based on seasonal averages. At the offshore station 90.90, summer DO has increased in recent years. Nearshore DO values are almost always lower than those offshore (93.30 vs. 90.90; see Fig. 3.3.1 and Appendix E.3).

In nearshore waters off Oregon (station NH5), aragonite levels at 40 m depth are typically saturated (>1.0) during the winter and spring, and then fall below 1.0 in the summer and fall; this was the case again in 2016 (Fig. 3.3.2). Further offshore (station NH25) and at 150 m depths, aragonite saturation state follows the same seasonal cycle but across a narrower range, and aragonite levels at this area and depth are almost always <1.0. However, aragonite levels have been elevated slightly in the anomalous conditions of the past two years. In fact, according to seasonal data, winter aragonite levels have increased over the past 5 years at both stations (Appendix E.3).

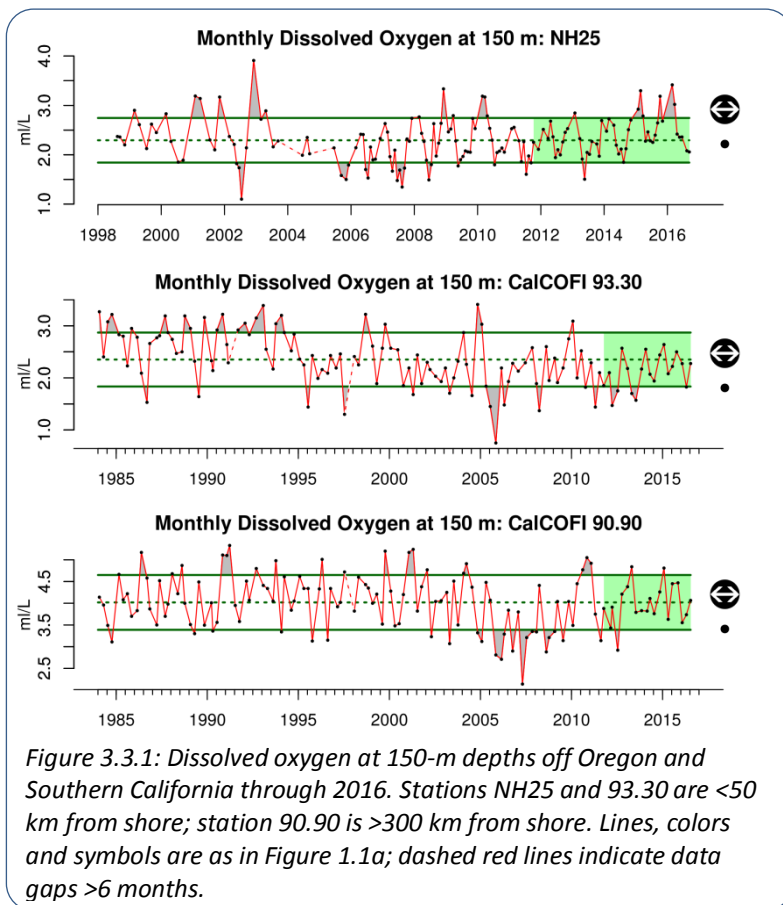


Figure 3.3.1: Dissolved oxygen at 150-m depths off Oregon and Southern California through 2016. Stations NH25 and 93.30 are <50 km from shore; station 90.90 is >300 km from shore. Lines, colors and symbols are as in Figure 1.1a; dashed red lines indicate data gaps >6 months.

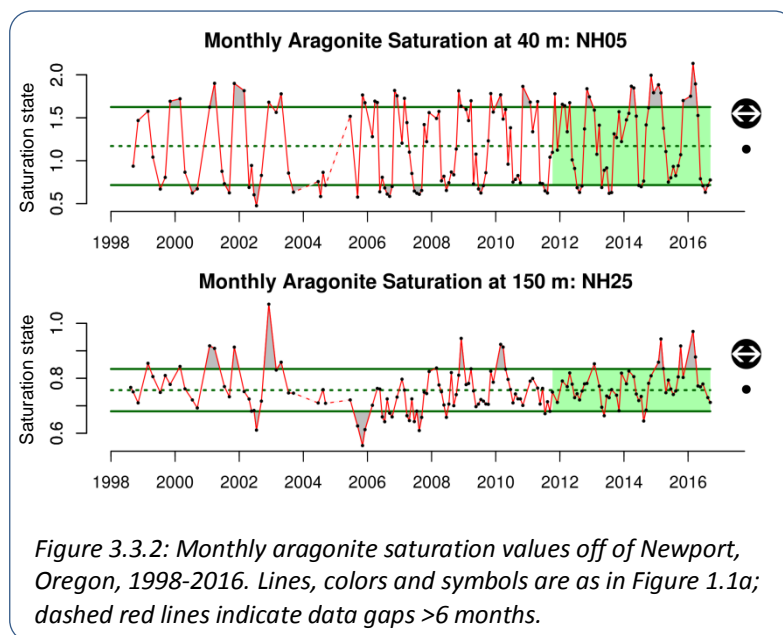


Figure 3.3.2: Monthly aragonite saturation values off of Newport, Oregon, 1998-2016. Lines, colors and symbols are as in Figure 1.1a; dashed red lines indicate data gaps >6 months.

### 3.4 HYDROLOGIC INDICATORS

Freshwater conditions are critical for salmon populations and for estuarine habitats that support many marine species (e.g., Appendix D). The freshwater indicators presented here focus on snowpack and streamflow, and are summarized by freshwater ecoregion (Fig. 2.1b). Snow-water equivalent (SWE) is the total water content in snowpack, which provides a steady source of freshwater into the summer months. Maximum streamflows in winter and spring are important for habitat formation, but can cause scouring of salmon nests. Minimum streamflows in summer and fall can restrict habitat for in-stream juveniles and migrating adults. All three indicators are influenced by climate and weather patterns and will be affected as climate change intensifies.

After years of steady declines and a historic low in 2015, SWE returned to average levels in all ecoregions in 2016 (Fig. 3.4.1). However, despite the rebound of SWE in early 2016, high spring and summer air temperatures resulted in rapid snowmelt. These factors led to an increase in maximum flows in 2016 (Appendix F), although not to levels considered dangerous to most salmon stocks. The early and rapid melt helped contribute to worsening trends in minimum flow in most of the ecoregions (see streamflow time series, Appendix F).

Following a series of winter storms, SWE in 2017 is on pace to exceed 2016 (see map in Appendix F, Fig. F.1) and may provide drought relief, although the official measure of SWE will not be until April 1, 2017.

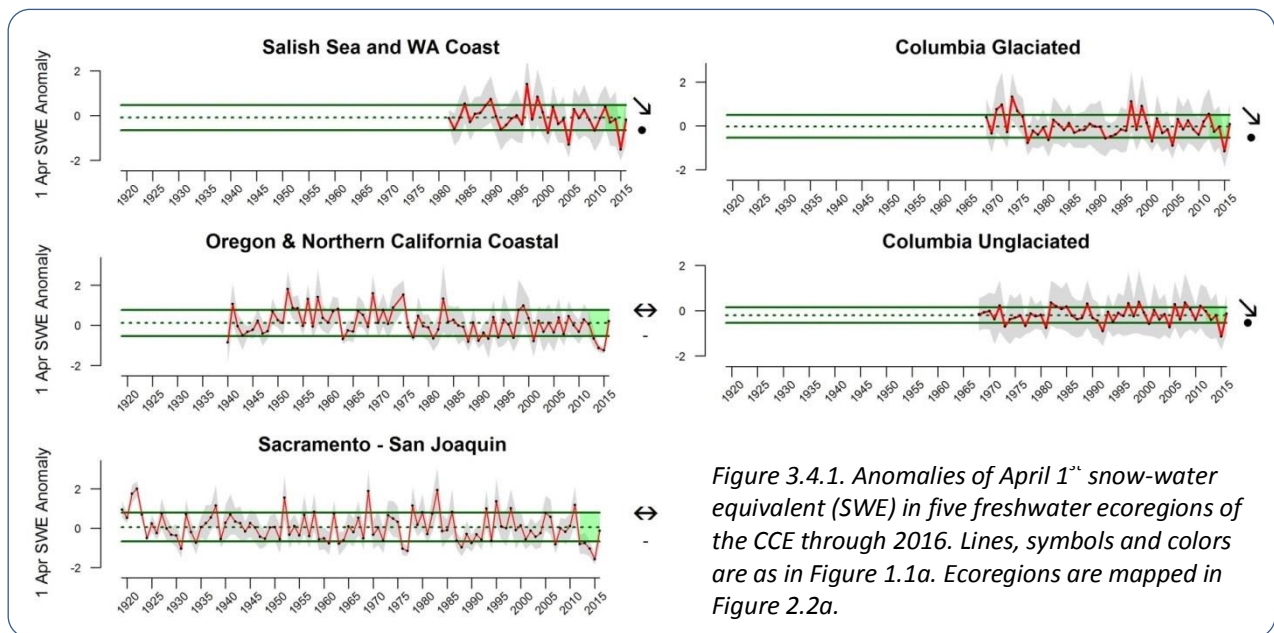
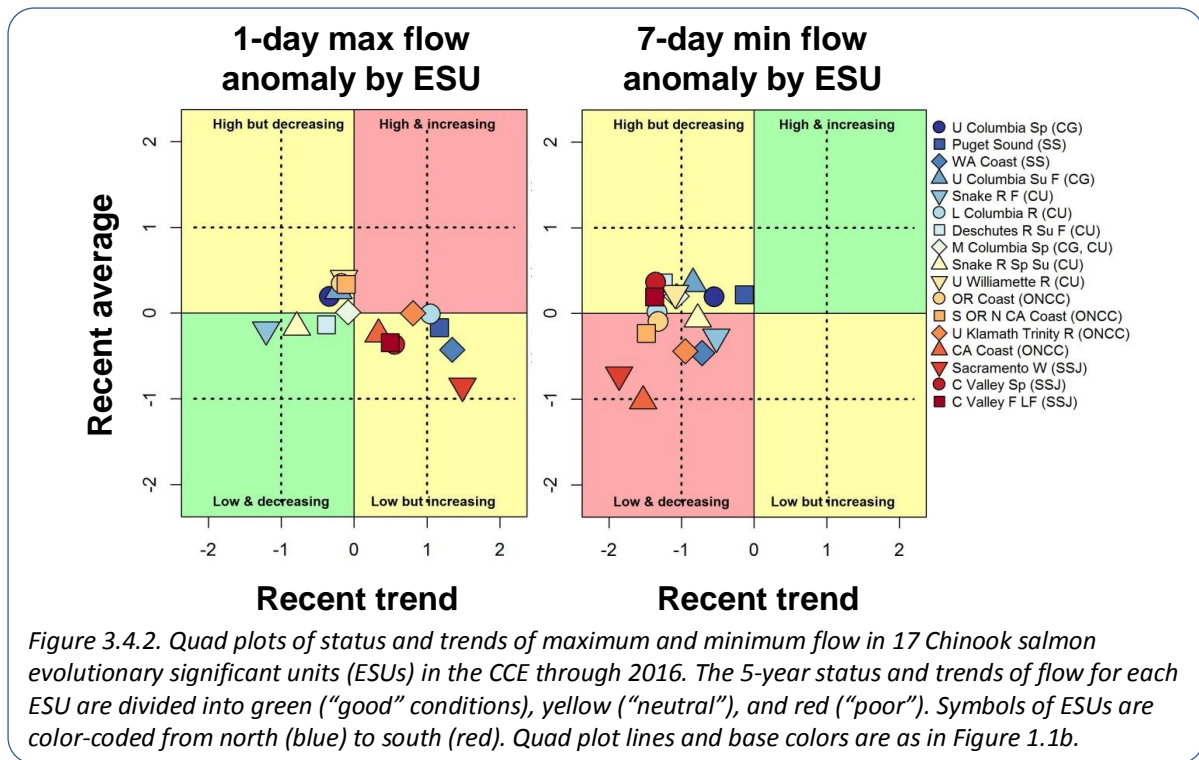


Figure 3.4.1. Anomalies of April 1<sup>st</sup> snow-water equivalent (SWE) in five freshwater ecoregions of the CCE through 2016. Lines, symbols and colors are as in Figure 1.1a. Ecoregions are mapped in Figure 2.2a.

We can also summarize streamflow using quad plots that summarize recent status and trends in flow anomalies at the finer spatial scale of individual Chinook salmon ESUs (Fig. 3.4.2). Here, high and increasing maximum flow is regarded as undesirable (i.e., the red quadrant of the max flow plot) due to the potential for scouring redds; low and decreasing minimum flow is also undesirable (the red quadrant of the min flow plot) because of potential for stress related to temperature, oxygen or space. The maximum flow events are within  $\pm 1$  s.d. of long-term averages and generally lack significant trends, although 4 ESUs indicate a recent increase (Fig 3.4.2, left). On the other hand, minimum flow anomalies have worsening trends for many ESUs, particularly those sensitive to low flow conditions, such as the Sacramento winter run and Klamath/Trinity ESUs. (Fig. 3.4.2, right).





#### 4 FOCAL COMPONENTS OF ECOLOGICAL INTEGRITY

The CCIEA team examines many indicators related to the abundance and condition of key species and the dynamics of community structure and ecological interactions. Many CCE species and processes respond very quickly to changes in ocean and climate drivers, while other responses may lag by many years. These dynamics are challenging to predict. Over the last several years, many ecological integrity metrics have indicated conditions of poor productivity at low trophic levels and poor foraging conditions for many predators. In 2016 we also continued to observe unexpected community structure in pelagic waters throughout the CCE. It remains to be seen how different populations have been affected, or whether 2017 will represent a shift away from the unproductive conditions observed since 2014.

##### 4.1 NORTHERN COPEPOD BIOMASS ANOMALY

Copepod biomass anomalies represent interannual variation in biomass of two groups of copepod taxa: northern copepods, which are “cold-water” species rich in wax esters and fatty acids that appear to be essential for pelagic fishes; and southern copepods, which are “warm-water” species that are generally smaller and have lower lipid content and nutritional quality. In summer, northern copepods usually dominate the coastal zooplankton community represented by collections along the Newport Line (see Fig. 2.1a,c), while Southern copepods dominate the community during winter. This pattern is often altered during El Niño events and/or when the PDO is positive, leading to higher biomass of southern copepods (Keister et al. 2011, Fisher et al. 2015). Threshold values for the anomalies have not been set, but positive values of northern copepods in summer are correlated with stronger returns of Chinook salmon to Bonneville Dam, and values greater than 0.2 are associated with better survival of coho salmon (Peterson et al. 2014).

With the exception of a brief period during summer 2015, the northern copepod anomaly has remained >1 s.d. below the long-term mean since the autumn of 2014 (Fig. 4.1.1, top). During this same period, the southern copepod biomass anomaly increased significantly and was strongly positive in much of 2016 (Fig. 4.1.1, bottom). These anomaly patterns are consistent with warm

surface waters and poor feeding conditions for pelagic fishes, and reflect a sustained departure from the generally productive ocean conditions for much of 2011-2014. Moreover, 17 species of copepods have been collected since autumn 2014 that had not been observed in these waters previously. It appears that many of these exotic copepod species were offshore, central Pacific species, not the typical southern species that are often transported northward to the Newport Line during major El Niño events.

#### 4.2 REGIONAL FORAGE AVAILABILITY

This section describes trends in forage availability, based on research cruises throughout the CCE through spring/summer 2016. These species represent a substantial portion of the available forage in the regions sampled by the cruises (see Fig. 2.1c). *We consider these regional indices of relative forage availability and variability, not indices of absolute abundance of coastal pelagic species (CPS).* Absolute abundance estimates should come from stock assessments and comprehensive monitoring programs, which these surveys are not. Moreover, the regional surveys that produce these data use different methods (e.g., gear selectivity, timing, frequency, and survey objectives); thus the amplitudes of each time series are not necessarily comparable between regions.

The CCE forage community is a diverse portfolio of species and life history stages, varying in behavior, energy density, and availability to predators. Years with abundant pelagic fish, market squid and krill are generally associated with cooler waters, strong upwelling and higher productivity (Santora et al. 2014, McClatchie et al. 2016). For space considerations, we present the forage indicators as quad plots in the main report; time series plots for each species and region are available in Appendix G.

*Northern CCE:* The northern CCE survey targets juvenile salmon in June in surface waters, but also catches juvenile and adult pelagic fishes, market squid, and gelatinous zooplankton. Except for jack mackerel, recent average catch-per-unit-effort (CPUE) of most forage species, were within 1 s.d. of the long-term mean and showed no discernable short-term trends (Fig. 4.2.1). Sardine and anchovy CPUE remained near the lowest levels observed in the time series (Appendix G, Fig. G.1). The two main species of gelatinous

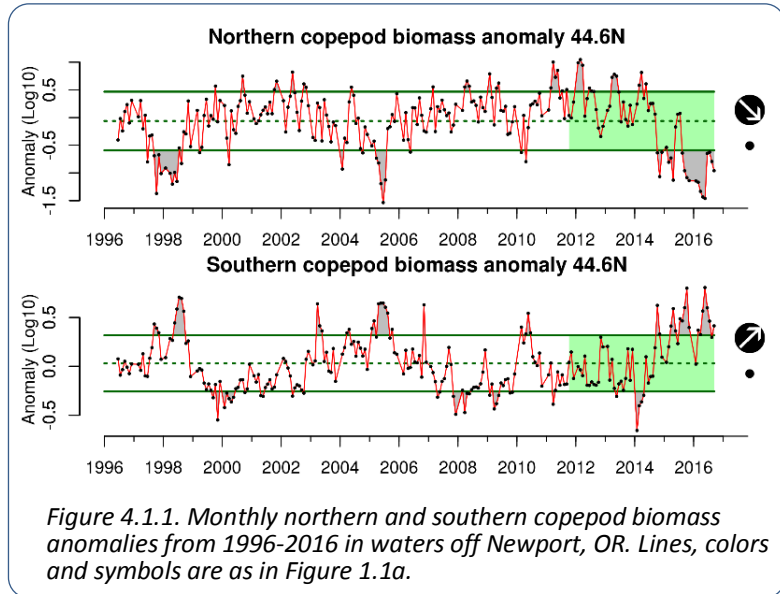


Figure 4.1.1. Monthly northern and southern copepod biomass anomalies from 1996-2016 in waters off Newport, OR. Lines, colors and symbols are as in Figure 1.1a.

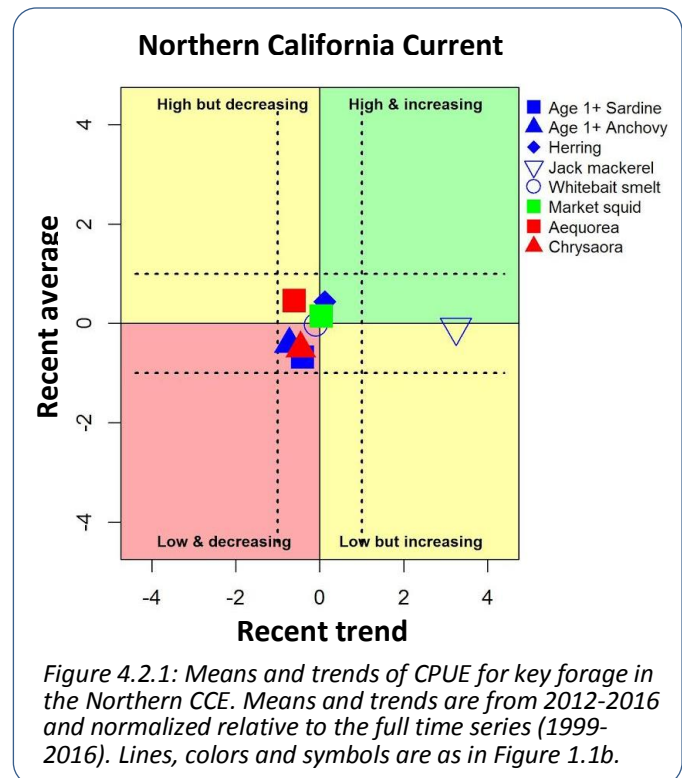


Figure 4.2.1: Means and trends of CPUE for key forage in the Northern CCE. Means and trends are from 2012-2016 and normalized relative to the full time series (1999-2016). Lines, colors and symbols are as in Figure 1.1b.

zooplankton were within the long-term mean range, although the small water jelly *Aequorea* sp. declined from 2015 and the large sea nettle *Chrysaora* was relatively uncommon. Anecdotally, a related survey in this region, which uses different methods and only began in 2011, caught many adult anchovy near the Columbia Plume, and saw evidence of anchovy spawning off Oregon in 2015 and 2016. This survey also showed a steep drop in krill in 2015 and 2016, concurrent with an increase in gelatinous salps. The survey also found young-of-the-year (YOY) rockfish and hake more abundant in 2016 than previous years.

**Central CCE:** Data presented here are from the “Core area” of a survey (see Fig. 2.1c) that targets YOY rockfishes, but also samples other forage fishes, market squid and zooplankton. The Central CCE forage community in 2016 exhibited many of the anomalous catch levels and trends observed in recent years. Adult sardine and anchovy CPUEs remained relatively low, whereas YOY rockfish CPUE was above average for the fourth year in a row (Fig. 4.2.2; see also Appendix G, Fig. G.2). YOY hake CPUE also maintained its recent increase, and YOY sanddabs remained above the long term mean. Krill and market squid CPUE have declined in recent years, particularly squid since 2014. *Chrysaora* jellyfish also declined, though that may be due to avoidance of sites where *Chrysaora* has fouled sampling gear in the past. However, salps were relatively abundant, as were warm-water species such as pelagic crabs (data not shown).

**Southern CCE:** The forage abundance indicators for the Southern CCE come from larval fish surveys conducted by CalCOFI. The larval biomass is assumed to correlate with the spawning stock biomass of forage species such as sardine, anchovy, market squid, shortbelly rockfish, and some mesopelagic species. Recent CPUE for the four species that have been analyzed through 2016 were within  $\pm 1$  s.d. of their long-term means, but anchovy showed a significant increasing trend while market squid show a recent decline (Fig. 4.2.3). The increase in larval anchovy CPUE in recent years (Appendix G, Fig. G.3) is consistent with anecdotal nearshore observations of large schools of adult anchovy.

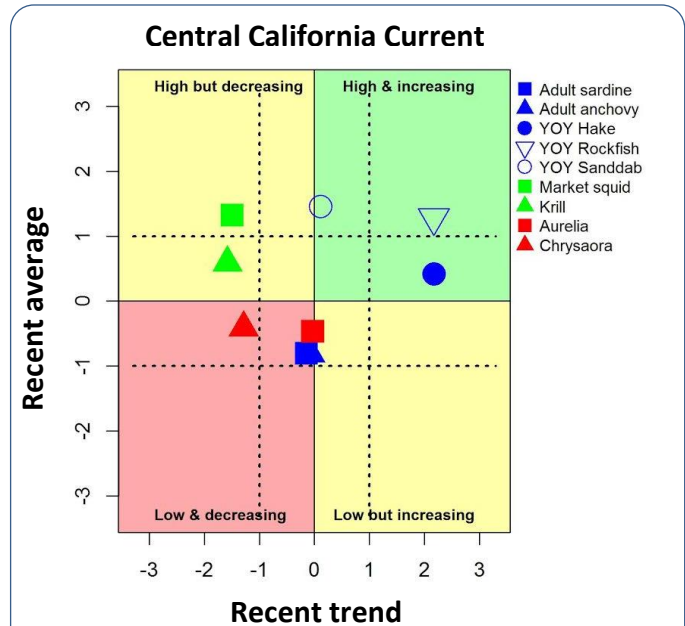


Figure 4.2.2 Means and trends of CPUE for key forage in the Central CCE (Core area). Means and trends are from 2012-2016 and normalized relative to the full time series (1990-2016). Lines, colors and symbols are as in Figure 1.1b.

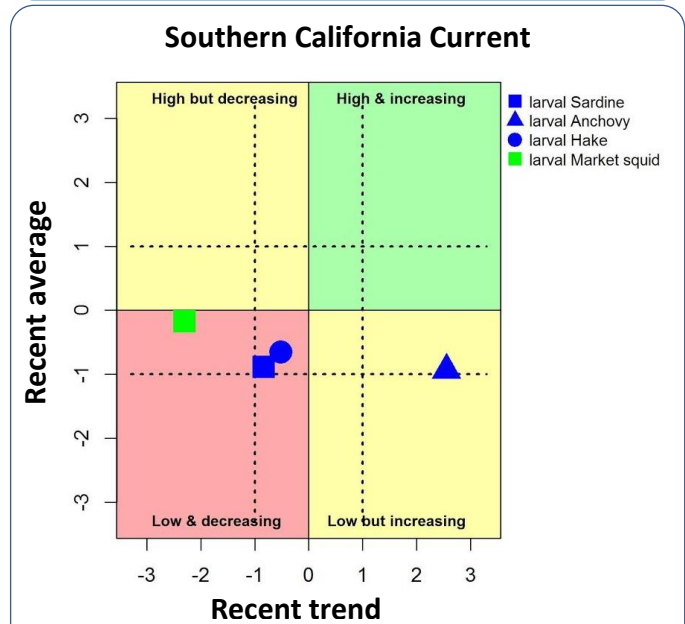


Figure 4.2.3 Means and trends of CPUE for key forage in the Southern CCE. Means and trends are from 2012-2016 and normalized relative to the full time series (1978-2016). Lines, colors and symbols are as in Figure 1.1b.

### 4.3 SALMON

For indicators of the abundance of Chinook salmon populations, we compare the trends in natural spawning escapement along the CCE to evaluate the coherence in production dynamics, and also to get a more complete perspective of their status across the greater portion of their range. When available, we use escapement time series back to the 1970s; however, some populations have shorter time series (for example, Central Valley Spring starts 1995, Central Valley Winter starts 2001, and Coastal California starts 1991). Here we present summary quad plots of escapements; full time series are available in Appendix H.

California Chinook salmon data are updated as of 2015. Generally, California Chinook salmon escapements were within 1 s.d. of their long-term averages (Fig. 4.3.1), although 2015 escapements were generally near the low end of the normal range (Appendix H, Fig. H.1). Most California stocks have neutral trends over the last decade, which is a noteworthy change from our last report: trends that had been positive for Central Valley Fall, Klamath Fall, California Coast and Northern CA/ Southern OR are now neutral after poor escapements in 2013, 2014 and/or 2015 (Appendix H, Fig. H.1). Central Valley Winter Run Chinook salmon have had relatively low escapements since 2007 following high escapements in 2005-2006, leading to the recent negative trend.

For Oregon, Washington and Idaho Chinook salmon stocks (updated through 2014), most recent escapements were close to average (Fig. 4.3.1). The exception is Snake River Fall Chinook after a series of large escapements since 2009 (Appendix H, Fig. H.2). Ten-year trends for northern stocks were either neutral or positive, with three (Lower Columbia, Snake River Fall and Snake River Spring) having significantly positive trends from 2005-2014.

Predicting exactly how the climate anomalies of 2013-2016 will affect different brood years of salmon from different parts of the CCE is difficult, despite concerted efforts by many researchers (e.g., Burke et al. 2013, Wells et al. 2016). However, many signs do suggest below-average returns may occur for Fall Chinook, Spring Chinook and coho stocks returning to the Columbia Basin. The poor hydrological conditions of 2015 (Section 3.4) were problematic for both juvenile and adult salmon. As noted above in Section 4.1, the Northern Copepod Biomass Anomaly is positively associated with Chinook and coho salmon returns in the Columbia River basin (Peterson et al. 2014), and its low levels in recent years do not portend well. The Northern Copepod Biomass Anomaly is just one part of a long-term effort by NOAA scientists to correlate oceanographic conditions and pelagic food web structure with salmon productivity (e.g., Burke et al. 2013). Their assessment is that physical and biological conditions for smolts that went to sea between 2013 and 2016 are generally consistent with poor returns of Chinook and coho salmon to much of the Columbia Basin in 2017, as depicted in the “stoplight chart” in Table 4.3.1.

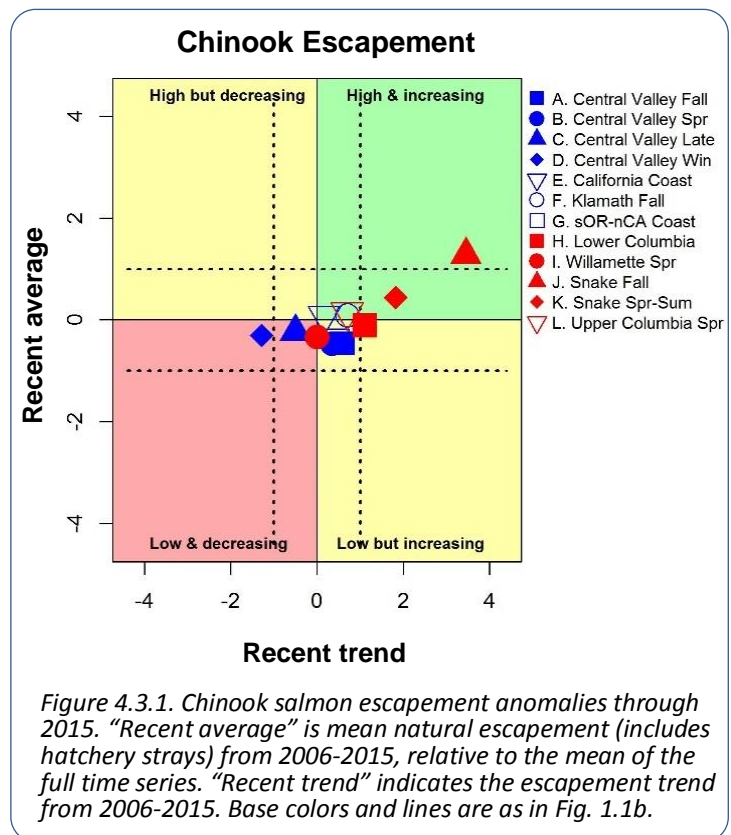
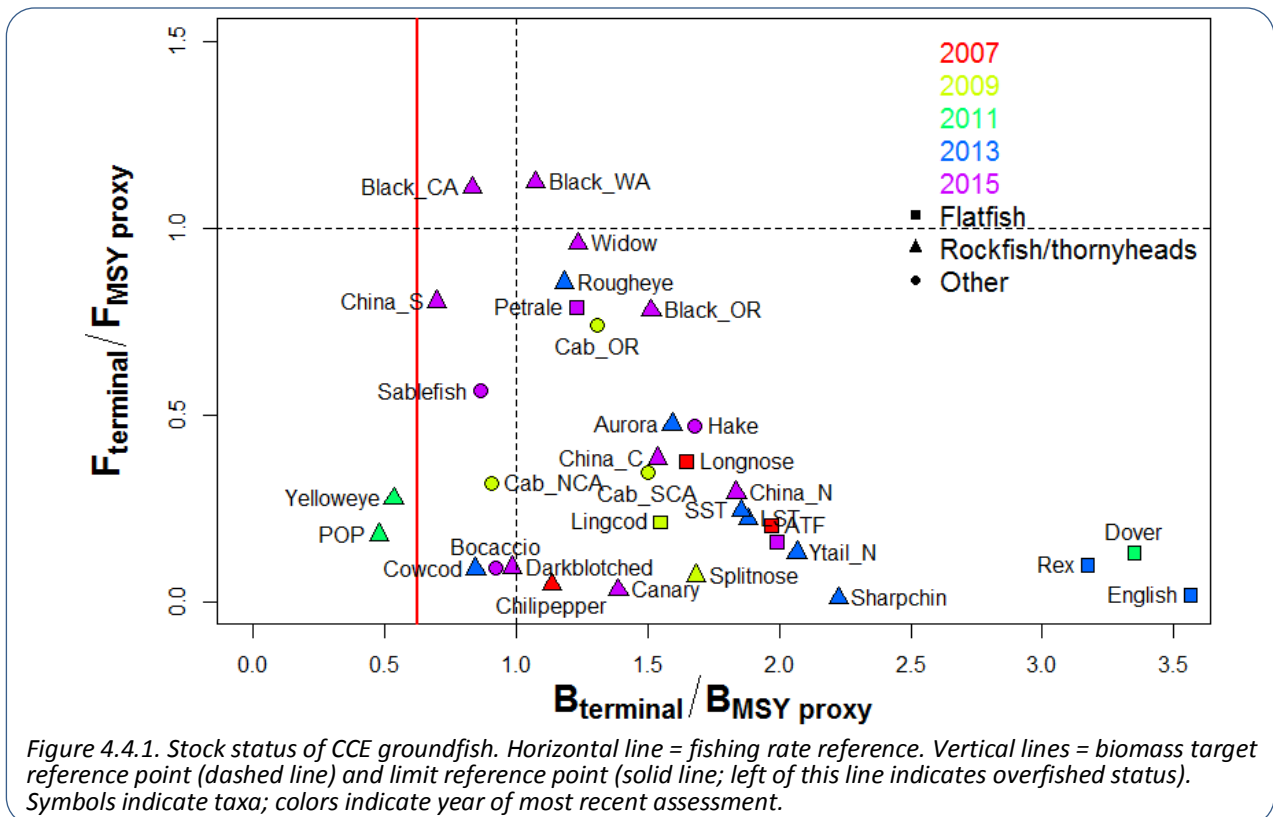


Table 4.3.1. "Stoplight" table of basin-scale and local-regional conditions for smolt years 2013-2016 and likely adult returns in 2017 for coho and Chinook salmon that inhabit coastal Oregon and Washington waters in their marine phase. Green = "good," yellow = "intermediate," and red = "poor." Courtesy of Dr. Bill Peterson (NWFSC).

Scale of indicators	Smolt year				Adult return outlook	
	2013	2014	2015	2016	Coho, 2017	Chinook, 2017
<b>Basin-scale</b>						
PDO (May-Sept)	Yellow	Yellow	Red	Red	Red	Red
ONI (Jan-Jun)	Yellow	Yellow	Red	Red	Red	Red
<b>Local and regional</b>						
SST anomalies	Yellow	Yellow	Red	Red	Red	Red
Deep water temp	Red	Red	Red	Yellow	Yellow	Red
Deep water salinity	Red	Red	Yellow	Yellow	Yellow	Yellow
Copepod biodiversity	Green	Yellow	Red	Red	Red	Red
Northern copepod anomaly	Green	Green	Red	Red	Red	Red
Biological spring transition	Green	Red	Red	Red	Red	Red
Winter ichthyoplankton biomass	Yellow	Red	Green	Green	Green	Green
Winter ichthyoplankton community	Yellow	Yellow	Red	Red	Red	Red
Juvenile Chinook catch (Jun)	Green	Yellow	Red	Yellow	Red	Red
Juvenile coho catch (Jun)	Green	Yellow	Yellow	Yellow	Yellow	Yellow

#### 4.4 GROUND FISH: STOCK ABUNDANCE AND COMMUNITY STRUCTURE

The CCIEA team regularly presents the status of groundfish biomass and fishing pressure based on the most recent stock assessments. Because 2016 was not a groundfish assessment year, we have no update from last year's report. Most of the recently assessed groundfish are near or above the biomass limit reference point, and are thus not in an "overfished" status (Fig. 4.4.1). The only exceptions were yelloweye rockfish and Pacific ocean perch, both last assessed in 2011.



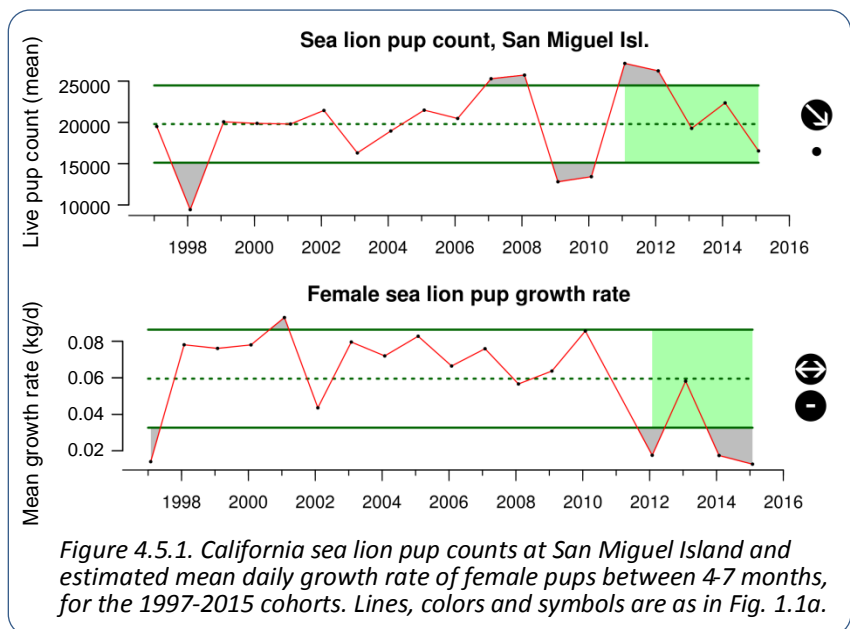
“Overfishing” occurs when catches exceed overfishing limits (OFLs), but not all assessed stocks are managed by individual OFLs. Our best alternative is to compare fishing rates to proxy fishing rates at maximum sustainable yield ( $F_{MSY}$ ), which are used to set OFL values. Only two stocks (black rockfish in California and Washington, both assessed in 2015) were being fished above  $F_{MSY}$  in their most recent assessments.

As noted in Section 4.2, YOY rockfish were highly abundant in the Central CCE in 2015 and 2016, and results from both shipboard and scuba surveys also revealed large numbers of pelagic and post-settled juvenile rockfish along the Washington coast in 2016. Given the anomalously warm and unproductive oceanographic conditions of 2013-2016, these findings run counter to what we might have expected from conceptual models linking climate and productivity conditions to groundfish populations (see Appendix D, Fig. D.2). It will be several years before these fish are large enough to be caught in bottom trawls; thus we will have to wait to determine how affect groundfish populations respond long-term to the recent climate anomalies.

We are also tracking the abundance of groundfish relative to Dungeness and Tanner crabs as a metric of seafloor community structure and trophic status. Due to space considerations, and because the time series are as yet short and difficult to interpret, we have moved these indicators from the main body to the Supplementary Materials, Appendix I.

#### 4.5 MARINE MAMMALS

California sea lions are permanent residents of the CCE, breeding on the Channel Islands and feeding throughout the CCE, and so are good indicators for the population status of pinnipeds in the system. California sea lions may also be sensitive indicators of prey availability in the central and southern CCE: sea lion pup count in the San Miguel Island breeding colony relates to prey availability for adult females during gestation (October-June), while pup growth is related to prey availability to adult females during the 11-month lactation period.



Over recent years, California sea lion adult females experienced extremely poor feeding conditions (Fig. 4.5.1). Pup counts declined from 2011-2015, and pup growth was near historic lows in at least three of the last five cohorts. These results, coupled with high rates of springtime pup stranding and mortality in 2013-2016, reflects the extent of poor foraging conditions for pinnipeds in the central and southern CCE and may foretell a decrease in the California sea lion adult population. Other pinniped species that breed in this region but forage further offshore (Guadalupe fur seals and northern fur seals) also experienced poor pup growth in the same time period.

Preliminary results suggest that the 2016 cohort of California sea lion pups at San Miguel was more abundant and experienced better early growth than the preceding four cohorts, implying that foraging conditions may have improved over the past year.

#### 4.6 SEABIRDS

Seabird species richness data were unavailable for this report, so we instead present regional time series for three key species. Sooty shearwaters migrate from the southern hemisphere to the CCE in spring and summer to prey on small fish and zooplankton near the shelf break. Common murres and Cassin’s auklets are resident species that feed over the shelf; Cassin’s auklets prey on zooplankton, while common murres target small fish.

In the northern sampling area (Fig. 2.1c), all three species exhibited temporal variability, particularly since the mid-2000s (Fig. 4.6.1). Sooty shearwaters have increased in recent years, while Cassin’s auklets declined in 2016, possibly related to an exceptional mortality event in 2014-2015. Common murre counts showed no trend. (Note: no data were collected in 2013 or 2014.)

In the longer southern time series, sooty shearwaters had increasing springtime density trends over the past five years (Fig. 4.6.2), which represents a return to densities observed in the late 1980s. Common murre densities had been minimal since data collection began in 1987 until an uptick in 2011, followed by strongly positive anomalies in 2015 and 2016. By contrast, Cassin’s auklets in the southern CCE have been just below average density over the last 10 years.

The positive density anomalies in recent years are surprising, given the recent and persistent warm conditions; for example, sooty shearwaters increased despite their cold-water affinities. These are abundance indicators of long-lived birds, however, and we may need condition indicators like diet, hatching rates, fledgling success, or others to fully understand recent seabird dynamics. To illustrate this, in each of the past several

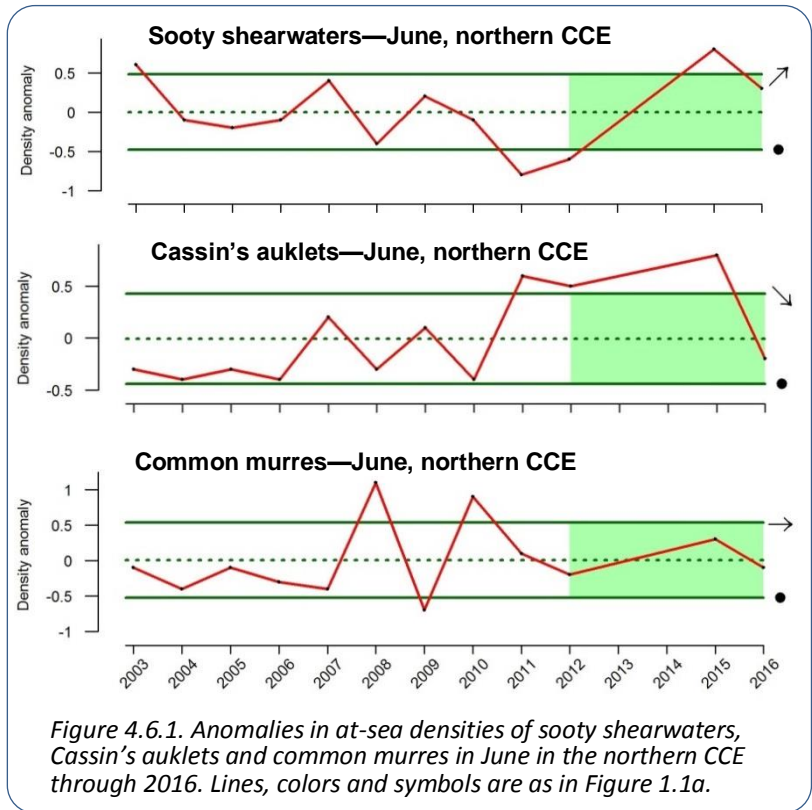


Figure 4.6.1. Anomalies in at-sea densities of sooty shearwaters, Cassin’s auklets and common murres in June in the northern CCE through 2016. Lines, colors and symbols are as in Figure 1.1a.

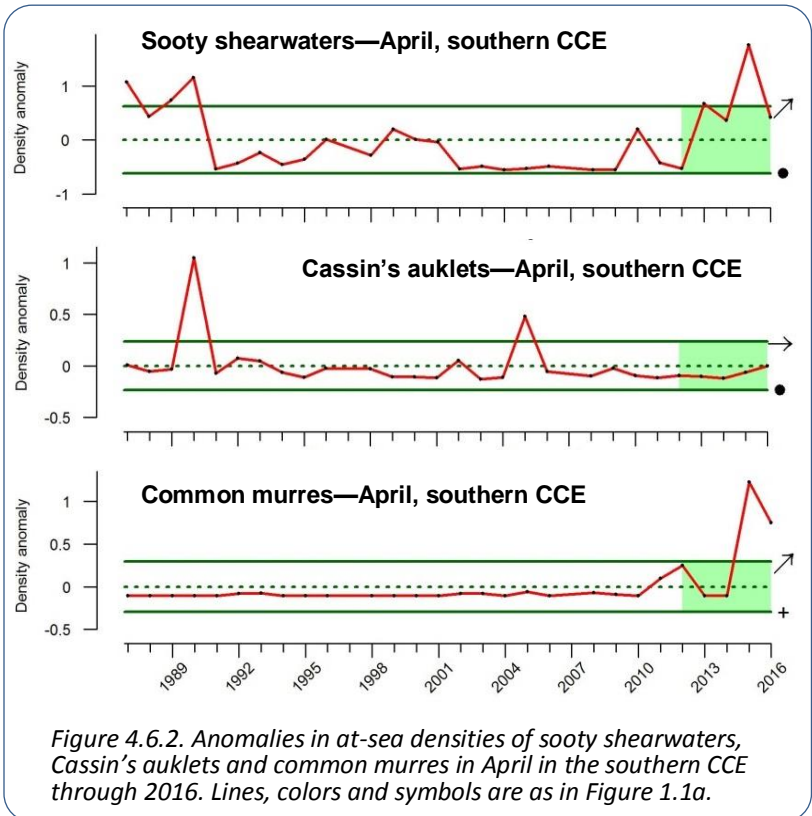


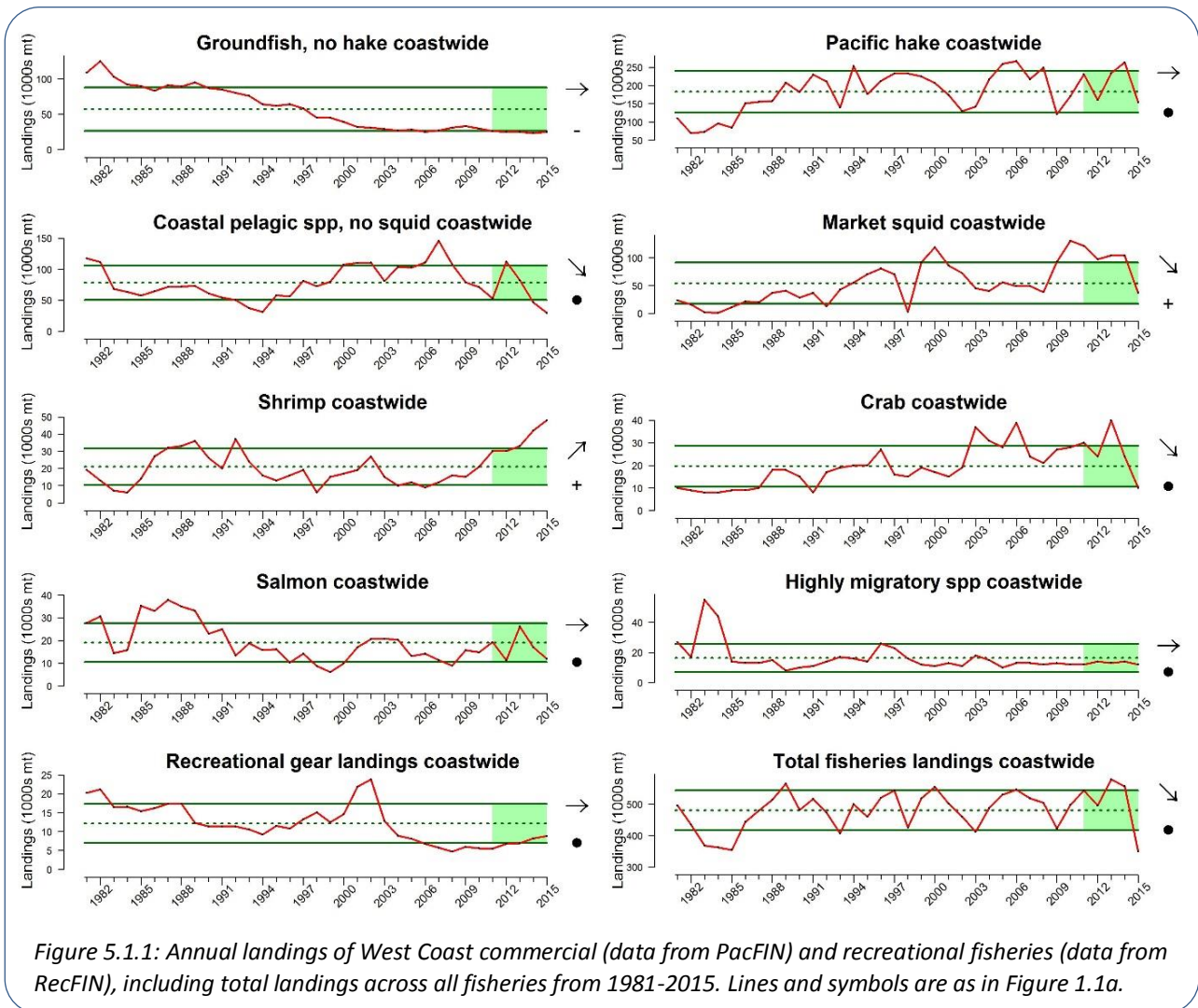
Figure 4.6.2. Anomalies in at-sea densities of sooty shearwaters, Cassin’s auklets and common murres in April in the southern CCE through 2016. Lines, colors and symbols are as in Figure 1.1a.

years, at least one seabird species has experienced a “wreck”—anomalously large numbers of dead birds washing up on beaches throughout much of the CCE (e.g., Cassin’s auklets in 2014, common murrelets in 2015). In the summer of 2016, rhinoceros auklets experienced a wreck, although it was largely confined to the northern CCE. The rhinoceros auklet wreck is described in Appendix J.

## 5. HUMAN ACTIVITIES

### 5.1 COASTWISE LANDINGS BY MAJOR FISHERIES

Data for fishery landings are current through 2015. Overall, total landings decreased over the last five years, driven mainly by steep declines in landings of Pacific hake, CPS and crab in 2015 (Fig. 5.1.1). Landings of groundfish (excluding hake) were historically low from 2011-2015, while hake landings were highly variable. Landings of CPS fishes and market squid decreased over the last five years. Shrimp landings increased to historic highs, particularly from 2013-2015, whereas crab declined sharply from a peak in 2013. Salmon landings were highly variable, while highly migratory species (HMS) landings were relatively consistent; both were within  $\pm 1$  s.d. of historic averages. Recreational landings were historically low from 2004-2015, and showed no recent trend. State-by-state commercial and recreational landings are summarized in Appendix K.





Revenues from commercial fishing, broken out by state and FMP, are also presented in Appendix K. Total commercial fishery revenues (in adjusted 2015 dollars) have declined sharply since 2013, driven by declines in landings of crab, market squid and hake (Appendix K, Figs. K.5-K.8).

## 5.2 GEAR CONTACT WITH SEAFLOOR

Benthic marine species, communities and habitats can be disturbed by natural processes as well as human activities (e.g., bottom contact fishing, mining, dredging). The impacts of fishing likely differ by gear and by habitat type, with hard, mixed and biogenic habitats needing longer to recover than soft sediments.

We compiled estimates of coast-wide distances affected by bottom-contact gear from 1999–2015. Estimates from 2002–2015 include bottom trawl and fixed gear, while 1999–2002 includes only bottom trawl data. We calculated trawling distances based on set and haul-back points, and fixed gear distances based on set and retrieval locations of pot, trap and longline gear. We weighted distances by gear and habitat type, according to sensitivity values described in Table A3a.2 of the 2013 Groundfish EFH Synthesis Report. Gear contact with the seafloor was at historically low levels over the most recent 5-year period (Fig. 5.2.1). The dominant signal is bottom trawl contact with soft sediments on the shelf and upper slope of the northern CCE (see Supplement, Appendix L). There is uncertainty in the estimation of bottom contact among fixed gear types (e.g. longline vs. pot and trap gear), but this uncertainty is minor compared to the signal from bottom trawl gear.

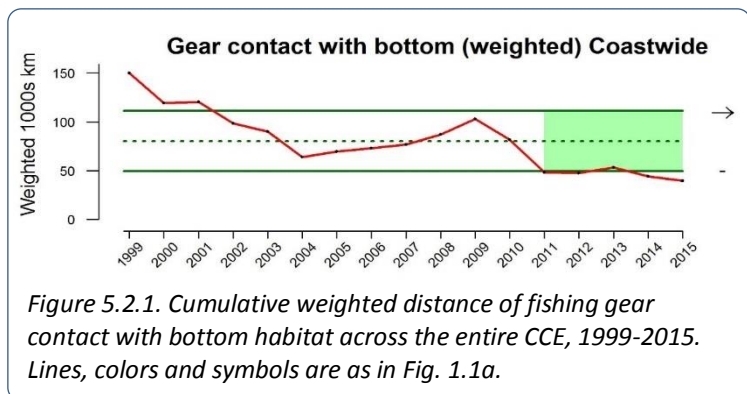


Figure 5.2.1. Cumulative weighted distance of fishing gear contact with bottom habitat across the entire CCE, 1999-2015. Lines, colors and symbols are as in Fig. 1.1a.

## 5.3 AQUACULTURE AND SEAFOOD DEMAND

Aquaculture activities are indicators of seafood demand and also may be related to benefits (e.g., water filtration by bivalves, nutrition, income, employment) or impacts (e.g., habitat conversion, waste discharge, species introductions). Shellfish aquaculture production in the CCE has been at historically high levels in recent years (updated through 2014 as of this report), and finfish aquaculture has been near the upper limits of historical averages (Fig. 5.3.1). Demand for seafood products increasingly is being met by aquaculture and may be influencing the increases in production.

Seafood demand in the U.S. was relatively constant from 2011-2015, and had largely recovered from decline late in the previous decade (Fig. 5.3.2). The recent average total consumption was above historical averages, while per capita demand was within the historic range. With total demand already at historically high levels, increasing populations and recommendations in U.S. Dietary Guidelines to increase seafood intake, total demand for seafood products seems likely continue to increase for the next several years.

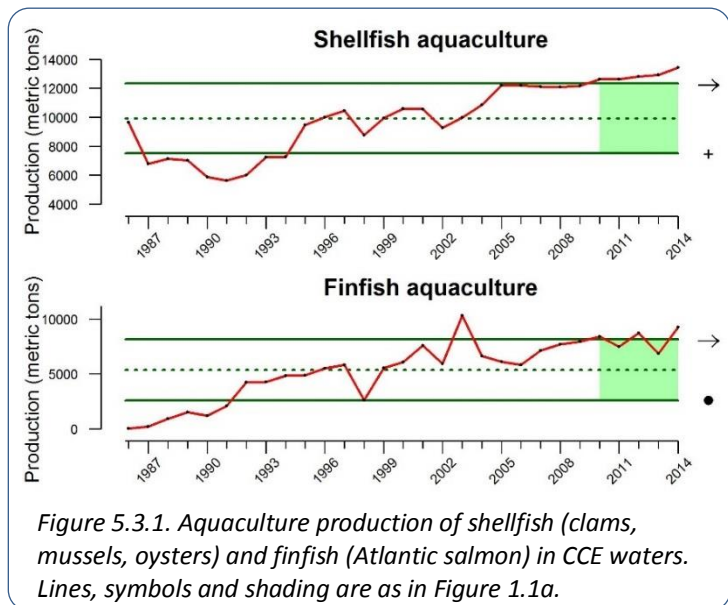
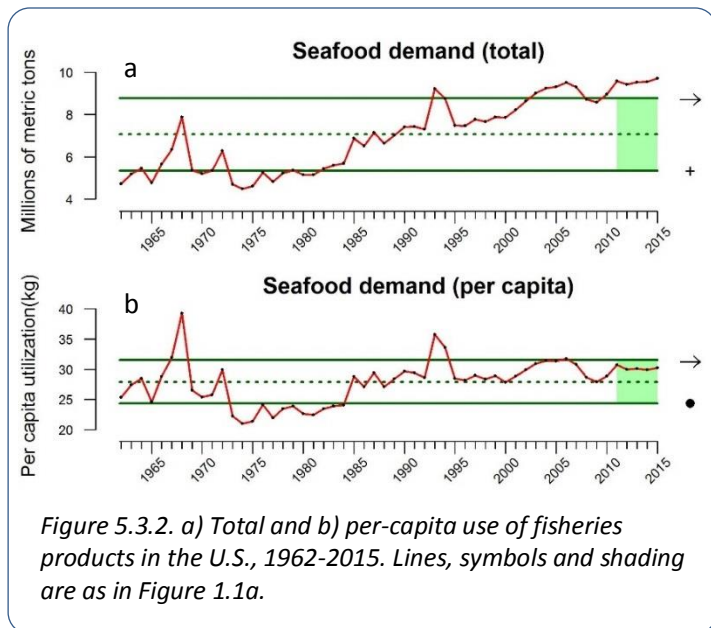


Figure 5.3.1. Aquaculture production of shellfish (clams, mussels, oysters) and finfish (Atlantic salmon) in CCE waters. Lines, symbols and shading are as in Figure 1.1a.

## 5.4 NON-FISHING ACTIVITIES

The CCIEA team compiles indicators of non-fisheries related human activities in the CCE, some of which may have effects on marine ecosystems, fisheries, and coastal communities. Among these activities are commercial shipping, nutrient inputs, and oil and gas activity. Since our last report in March 2016, we have received little new data for these three activities, and thus have placed information on them in the Supplementary Materials (Appendix M). It suffices to say that commercial shipping and oil and gas activity were at relatively low, stable levels through 2013-2015, while data on nutrient inputs are only available through 2012 and thus are not reliable for assessing present status and trends.



## 6. HUMAN WELLBEING

### 6.1. SOCIAL VULNERABILITY

Coastal community vulnerability indices are generalized socioeconomic vulnerability metrics for communities involved in commercial fishing. To assess social vulnerability in fishery-dependent communities, we use community-level social data, port-level fish ticket data, and a factor analysis approach to generate composite social vulnerability and commercial fishing indices for 1139 coastal communities. The Community Social Vulnerability Index (CSVI) is derived from social vulnerability data (demographics, personal disruption, poverty, housing characteristics, housing disruption, labor force structure, natural resource labor force, etc.). The fishing dependence composite index is based on commercial fishing engagement in a community (including fishery landings, revenues, permits, and processing) and commercial fishing reliance (per capita engagement). Figure 6.1.1 shows both indices for 25 highly fishing-dependent communities in five regions of the West Coast. Scores are relative to the entire CCE; for example, in 2014 the commercial fishing dependence of Moss Landing was ~33 standard deviations greater than the average community. The ten most fishery-dependent communities and their vulnerability scores are presented in Appendix N.

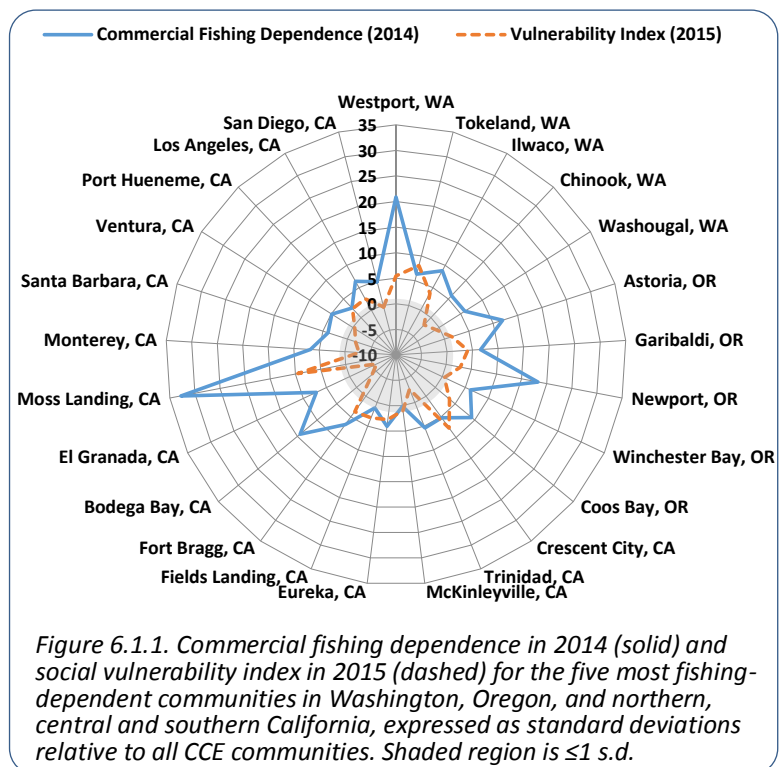


Figure 6.1.2 shows the two indices in x-y space, allowing us to readily identify fishing-dependent communities with high social vulnerability. Of note are communities like Moss Landing and Westport, which have relatively high commercial fishing dependence (~33 and 21 s.d. above average) and also a high CSVI (~10 and 5 s.d. above average). Communities that are strong outliers in both indices may be particularly socioeconomically vulnerable to a downturn in commercial fishing. Exogenous shocks of a management-related or ecosystem-related nature may produce especially high individual and community-level social stress in these communities.

We now have enough data from the US Census and the American Community Survey for a 2000-2015 time series of community vulnerability in relation to commercial fishery dependence. This time series focuses on ten commercial fishing-dependent communities that consistently scored among the most socially vulnerable in all years. Because this time series has only four data points, it remains volatile and difficult to interpret, and is thus in the Supplement (Appendix N). We will further develop this time series, although doing so is constrained by the fact that census data are only collected every five years.

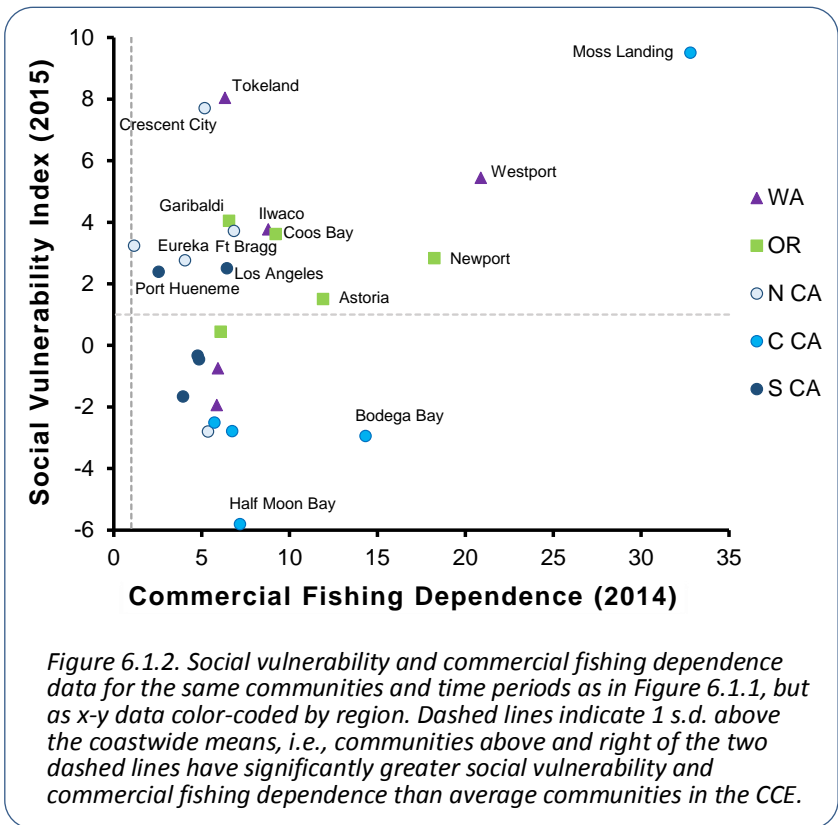
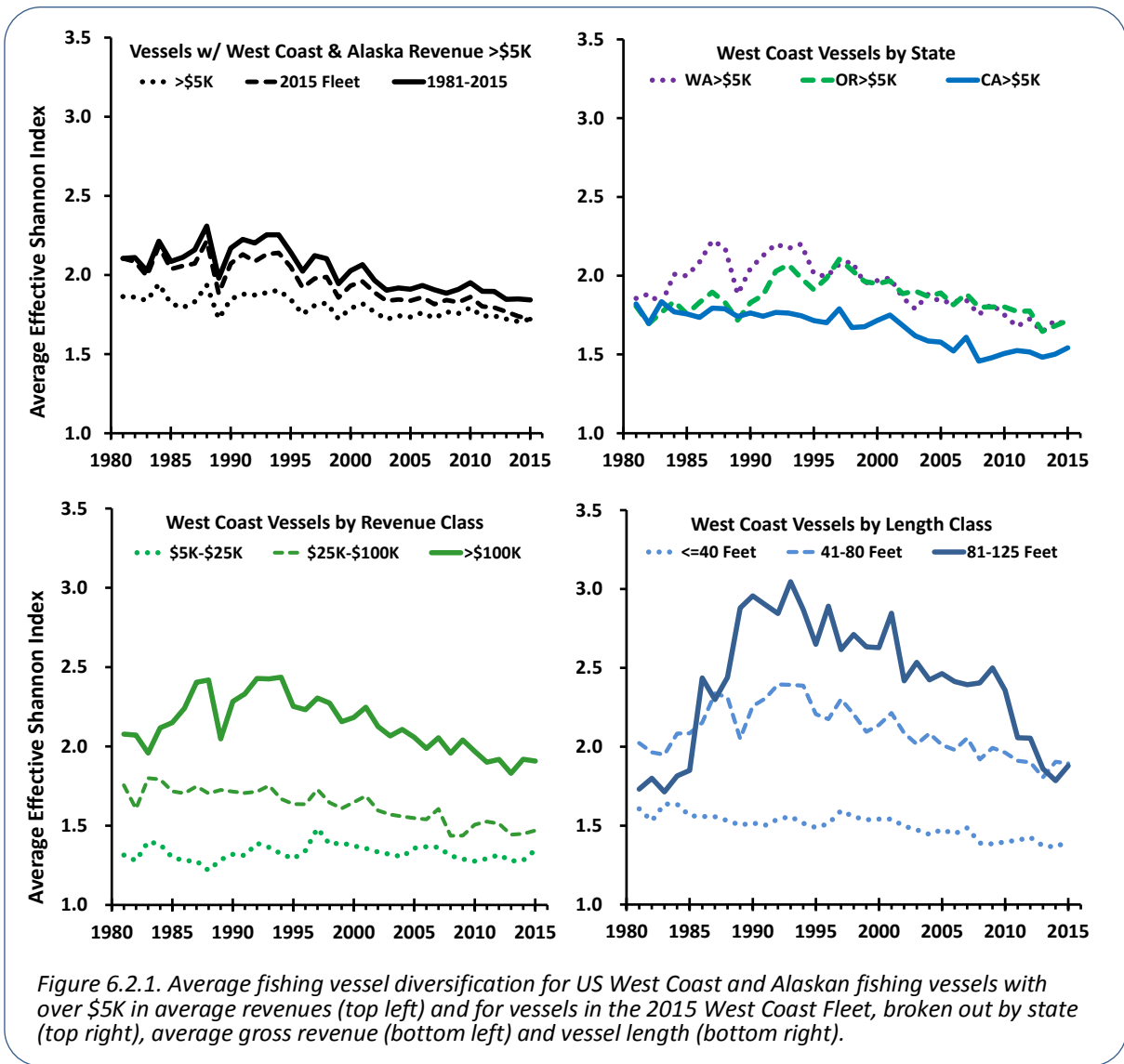


Figure 6.1.2. Social vulnerability and commercial fishing dependence data for the same communities and time periods as in Figure 6.1.1, but as x-y data color-coded by region. Dashed lines indicate 1 s.d. above the coastwide means, i.e., communities above and right of the two dashed lines have significantly greater social vulnerability and commercial fishing dependence than average communities in the CCE.

## 6.2 FLEET DIVERSITY INDICES

Catches and prices from many fisheries exhibit high interannual variability, leading to high variability in fishers' income. Variability in annual revenue can be reduced by diversifying fishing activities across multiple fisheries or regions (Kasperski and Holland 2013). There may be good reasons for individuals to specialize, however, including reduced costs or greater efficiency. Thus, while diversification may reduce income variation, it does not necessarily promote higher average profitability. We measure diversification with the Effective Shannon Index (ESI). ESI = 1 when revenues are all from a single species group and region. It increases both as revenues are spread across *more* fisheries and as revenues are spread more *evenly* across fisheries. The index has an intuitive meaning: ESI = 2 if fishery revenues are spread evenly across 2 fisheries; ESI = 3 if revenues are spread evenly across 3 fisheries; and so on. If revenue is not evenly distributed across multiple fisheries, the ESI value is lower than the number of fisheries. As of 2015, the fleet of vessels fishing on the US West Coast and in Alaska is less diverse on average than at any point in the past 35 years (Fig. 6.2.1). Between 2014 and 2015, some categories of vessels showed a small increase in ESI, while others decreased, but absolute changes were minor. The only fleet to change by >2 s.d. were vessels 81-125 feet, for which ESI increased by about 5%; this change appears to be due to non-participation of some less-diversified vessels from West Coast fisheries in 2015. The long-term decrease in ESI over the last 35 years is due both to entry and exit of vessels and changes for



individual vessels. Over time, less-diversified vessels have been more likely to exit, which increases average diversification. However, vessels that remain in the fishery have also become less diversified, at least since the mid-1990s, and newer entrants have generally been less diversified than earlier entrants. The overall result is a moderate decline in ESI since the mid-1990s or earlier for most vessel groupings. Notwithstanding these average trends, there are wide ranges of diversification levels and strategies within as well as across vessel classes, and some vessels remain highly diversified. It should be noted that increases in diversification from one year to the next may not always indicate a positive improvement. For example, if a class of vessels was heavily dependent on a single fishery with highly variably revenues, such as Dungeness crab, an overall decline in the Dungeness crab fishery might cause ESI to increase. Also an increase in ESI may be due to the exit of less diversified vessels. Additional break-downs of diversification are in Appendix O of the Supplement.

## 7. RESEARCH RECOMMENDATIONS

In March 2015, the Council approved FEP Initiative 2, “Coordinated Ecosystem Indicator Review” (Agenda Item E.2.b), by which the Council, advisory bodies, the public, and the CCIEA team would work jointly to refine the indicators in the annual CCIEA Ecosystem Status Report to better meet Council objectives. The Initiative was implemented by an ad-hoc Ecosystem Working Group (EWG).

The EWG asked the CCIEA team to include a short section of “Research Recommendations” in the 2017 report. The Recommendations below reflect our collective assessment of science products that we believe are important; that we could provide to the Council in a reasonable time frame (e.g., 1-3 years, including technical review by the SSC Ecosystem Subcommittee); that fit with developing NOAA Ecosystem-Based Fisheries Management (EBFM) Road Map; and that would provide added value to the indicators as they relate to management of FMP stocks and protected species.

### 7.1 CONTINUE AN ONGOING SCOPING PROCESS BETWEEN THE COUNCIL AND THE CCIEA

The CCIEA team recognizes the necessity to partner directly with the Council on these Research Recommendations, in order for them to be effective and directly applicable to management. We greatly appreciated the time and effort the Council gave to scoping the contents of this annual report under FEP Initiative 2. An ongoing scoping process could give the CCIEA team clear direction on Council needs, and give the Council a clear sense of CCIEA capabilities and capacity. Therefore:

- *The Research Recommendations below are based on our current work and interests, but we would appreciate an opportunity to further scope CCIEA work with the Council and its advisory bodies, to ensure that our work is aligned with the Council’s ecosystem science needs.*

### 7.2 CONTINUE MAKING IMPROVEMENTS TO INDICATOR ANALYSIS

The CCIEA team has benefited greatly from working with the EWG on the Initiative, and from the complementary support of the SSC in providing technical review of CCIEA indicators and activities. The CCIEA team recommends that this partnership continue, with emphasis on:

- *Continued refining of the existing indicators in this report, to better meet Council needs;*
- *Identifying and prioritizing indicator gaps, such as CPS, HMS, groundfish, diet information, chlorophyll, harmful algal blooms, and socioeconomic data from underreported communities;*
- *Using multivariate autoregressive state-space (MARSS) models to estimate trends in our indicators, separate from the observation error inherent in field sampling;*
- *Analyzing time series to (1) determine if threshold relationships exist between stressors and indicators, to inform risk assessments; and (2) to detect early warning indicators of major shifts in ecosystem structure or function.*

### 7.3 ASSESS DYNAMICS OF FISHERIES ADAPTATION TO SHORT-TERM CLIMATE VARIABILITY

The CCE is highly variable, driven by annual or decadal variations such as El Niño events, PDO shifts, and marine heat waves. The livelihoods of fishers in the CCE are heavily influenced by such variability. As fishers attempt to adapt to variability by switching among fisheries, their actions impact other fishers and fishing communities, and may actively influence ecosystem dynamics. This project will investigate how fisheries management and fishers’ fishing strategies combine to effect social and ecological resilience to the short-term climate variability inherent to the CCE. We plan to:

- *Analyze how productivity of key species varies with climate/ocean conditions;*
- *Survey CCE fishers to determine motivations for fishery participation, and use the data from the survey and fish tickets to fit statistical models of individual fishing participation choices;*
- *Construct an integrated model of several CCE fisheries (e.g., salmon, Dungeness crab, albacore, groundfish, shrimp) that determines participation and effort in each fishery;*

- *Model how climate variability affects fisheries both directly via environmental effects and indirectly via participation decisions, and explore what types of fishing portfolios, for individuals or ports, result in lower variation in income and higher quality of life.*

#### **7.4 ASSESS VULNERABILITY OF “COMMUNITIES AT SEA” TO LONG-TERM CLIMATE CHANGE**

Long-term climate change has already shifted distributions of marine species in the CCE, but the socio-ecological impacts of climate change on fishing communities over the next several decades are difficult to anticipate. A major challenge remains linking vulnerability to predicted long-term changes in the marine seascape upon which each community depends, particularly because both target species and fleets from different ports form spatially and temporally dynamic “communities at sea” (e.g., Colburn et al. 2016). We plan to:

- *Develop a composite index of vulnerability for each community at sea as a function of its exposure (changes in target species biomass) and sensitivity (dependence on each target species) to long-term climate change;*
- *Assess each community at sea’s adaptive capacity (e.g., mobility, target switching);*
- *Set up Environmental Competency Groups throughout the CCE, so that scientists, fishers and managers can together interrogate information about climate vulnerabilities and impacts, co-develop adaptation strategies, and proactively reveal barriers to adaptation.*

#### **7.5 “DYNAMIC OCEAN MANAGEMENT” TO REDUCE BYCATCH IN HMS FISHERIES**

Traditional management measures for bycatch reduction are static in space and time, despite the fact that both marine species and human users rely on dynamic environmental features. Dynamic Ocean Management (DOM) offers an ecosystem-based management approach toward addressing these dynamic issues (Lewison et al. 2015). We define DOM as management of marine systems that can change in space and time with the shifting nature of the ocean and its users. We are exploring DOM for HMS, specifically to maximize swordfish catch in the California drift gillnet fishery while minimizing bycatch of key species including leatherback sea turtles, blue sharks, and California sea lions; we will extend this to include marine mammals that are hard cap species. Our approach is to:

- *Use species-specific bycatch risk profiles to create risk-reward ratios for swordfish vessels;*
- *Track spatiotemporal changes in risk ratios as a function of management strategies and dynamic environmental conditions in the area of the drift gillnet fishery.*

#### **7.6 ASSESS ECOLOGICAL AND ECONOMIC IMPACTS OF OCEAN ACIDIFICATION**

The CCE is characterized by upwelling of deep, cold, nutrient-rich waters that support fish stocks and the human communities that rely on them, but that also make the area particularly at risk of OA. The CCIEA team is leading focused research to identify the species, fisheries, and ports most vulnerable to OA. This will address needs identified in PFMC Fishery Ecosystem Plan Initiative A.2.8, by the Ecosystem Advisory Subpanel, and in the NOAA Fisheries Climate Science Strategy Western Regional Action Plan (WRAP). Specifically, we will:

- *Apply an Atlantis ecosystem model, which was formally reviewed by the SSC in July 2014, and presented to the full Council in November 2014 (Kaplan and Marshall 2016);*
- *Link the Atlantis model to 1) ensembles of future scenarios for OA, warming, and species range shifts, and 2) updated information about species exposure and sensitivity to OA;*
- *Identify FMPs, ecoregions, and ports most likely affected by OA, warming, and subsequent range shifts, including both direct and indirect (e.g. food web) effects;*
- *Consider impacts on FMPs that result from changes in prey productivity, for instance impacts on rebuilding rockfish stocks.*

**SUPPLEMENTARY MATERIALS**  
TO THE  
**CALIFORNIA CURRENT INTEGRATED ECOSYSTEM ASSESSMENT (CCIEA)**  
**CALIFORNIA CURRENT ECOSYSTEM STATUS REPORT, 2017**

Appendix A: List of Contributors and Affiliations

Appendix B: List of Figure and Data Sources for the Main Report

Appendix C: Changes in this Year's Report, in Response to Council and Advisory Body Comments

Appendix D: Conceptual Models of the California Current

Appendix E: Climate and Ocean Indicators

Appendix F: Habitat Indicators: Snow-Water Equivalent and Streamflow

Appendix G: Regional Forage Availability Indicators

Appendix H: Chinook Salmon Escapement Indicators

Appendix I: Demersal Community Structure

Appendix J: The 2016 Rhinoceros Auklet Mortality Event

Appendix K: State-by-State Fishery Landings and Revenues

Appendix L: Fishing Gear Contact with Seafloor Habitat

Appendix M: Other Non-Fisheries Human Activities Indicators

Appendix N: Social Vulnerability of Commercial Fishing-Dependent Communities

Appendix O: Fleet Diversification Indicators for Major West Coast Ports

Appendix P: References

Appendix Q: List of Acronyms Used in this Report

## **APPENDIX A. LIST OF CONTRIBUTORS TO THIS REPORT, BY AFFILIATIONS**

### SWFSC, NOAA Fisheries

Dr. Newell (Toby) Garfield (co-editor; Toby.Garfield@noaa.gov)  
Dr. Steven Bograd  
Ms. Lynn deWitt  
Dr. John Field  
Dr. Elliott Hazen  
Dr. Michael Jacox  
Dr. Andrew Leising  
Dr. Isaac Schroeder  
Dr. Andrew Thompson  
Dr. Brian Wells  
Dr. Thomas Williams

### NWFSC, NOAA Fisheries

Dr. Chris Harvey (co-editor; Chris.Harvey@noaa.gov)  
Mr. Kelly Andrews  
Ms. Katie Barnas  
Dr. Richard Brodeur  
Dr. Jason Cope  
Dr. Correigh Greene  
Dr. Thomas Good  
Dr. Daniel Holland  
Ms. Su Kim  
Dr. Stuart Munsch  
Dr. Karma Norman  
Dr. Bill Peterson  
Dr. Melissa Poe  
Dr. Jameal Samhour  
Dr. Nick Tolimieri  
Ms. Anna Varney  
Mr. Gregory Williams  
Dr. Jeannette Zamon

### AFSC, NOAA Fisheries

Dr. Stephen Kasperski  
Dr. Sharon Melin

### Farallon Institute

Dr. William Sydeman  
Dr. Julie Thayer

### Oregon State University

Ms. Caren Barcelo  
Ms. Jennifer Fisher



## APPENDIX B. LIST OF FIGURE AND DATA SOURCES FOR THE MAIN REPORT

Figure 3.1: Newport Hydrographic (NH) line temperature data are from Dr. Bill Peterson (NOAA). CalCOFI hydrographic line data are from <http://calcofi.org/data.html>. CalCOFI data before 2016 are from the bottle data CSV database, while 2016 data are preliminary data from the CTD CSV database.

Figure 3.1.1: Oceanic Niño Index information and data are from the NOAA Climate Prediction Center ([http://www.cpc.ncep.noaa.gov/products/analysis\\_monitoring/ensostuff/ONI\\_change.shtml](http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ONI_change.shtml)). Pacific Decadal Oscillation data are from Dr. Nate Mantua (NOAA) and are served by the University of Washington Joint Institute for the study of the Atmospheric and Ocean (JISAO; <http://research.jisao.washington.edu/pdo/>). North Pacific Gyre Oscillation data are from Dr. Emanuele Di Lorenzo (Georgia Institute of Technology) (<http://www.o3d.org/npgo/>).

Figure 3.1.2: Sea surface temperature maps are optimally interpolated remotely-sensed temperatures (Reynolds et al. 2007). The daily optimal interpolated AVHRR SST can be downloaded using ERDDAP (<http://upwell.pfeg.noaa.gov/erddap/griddap/ncdcOisst2Agg.html>).

Figure 3.2.1: Cumulative Upwelling Index curves are calculated from the six-hourly upwelling index product (<http://upwell.pfeg.noaa.gov/erddap/taledap/erdUI216hr.html>).

Figure 3.3.1: Newport Hydrographic (NH) line dissolved oxygen data are from Dr. Bill Peterson (NOAA). CalCOFI hydrographic line data are from <http://calcofi.org/data.html>. Note: CalCOFI data before 2016 are from the bottle data CSV database, while 2016 data are preliminary data from the CTD CSV database.

Figure 3.3.2: Aragonite saturation state data were provided by Dr. Bill Peterson (NOAA).

Figure 3.4.1: Snow-water equivalent data were derived from the California Department of Water Resources snow survey (<http://cdec.water.ca.gov/>) and the Natural Resources Conservation Service's SNOTEL sites in WA, OR, CA and ID (<http://www.wcc.nrcs.usda.gov/snow/>).

Figure 3.4.2: Minimum and maximum streamflow data were provided by the US Geological Survey (<http://waterdata.usgs.gov/nwis/sw>).

Figure 4.1.1: Copepod biomass anomaly data were provided by Dr. Bill Peterson (NOAA).

Figure 4.2.1: Pelagic forage data from the Northern CCE were provided by Dr. Ric Brodeur (NOAA) and were derived from surface trawls conducted as part of the BPA Plume Survey.

Figure 4.2.2: Pelagic forage data from the Central CCE were provided by Dr. John Field (NOAA) from the SWFSC Rockfish Recruitment and Ecosystem Assessment Survey (<https://swfsc.noaa.gov/textblock.aspx?Division=FED&ParentMenuId=54&id=20615>).

Figure 4.2.3: Pelagic forage data from the Southern CCE were provided by Dr. Andrew Thompson (NOAA) and were derived from spring CalCOFI surveys (<http://calcofi.org/>).

Figure 4.3.1: Chinook salmon escapement data were derived from the California Department of Fish and Wildlife (<http://www.dfg.ca.gov/fish/Resources/Chinook/CValleyAssessment.asp>), from Pacific Fishery Management Council pre-season reports (<http://www.pcouncil.org/salmon/stock-assessment-and-fishery-evaluation-safe-documents/preseason-reports/2016-preseason-report-i/>) and from the NOAA Northwest Fisheries Science Center's "Salmon Population Summary" database (<https://www.webapps.nwfsc.noaa.gov/sps>).

Table 4.3.1: Stoplight table of indicators and 2016 salmon returns provided by Dr. Bill Peterson (NOAA).

Figure 4.4.1: Groundfish stock status data were provided by Dr. Jason Cope (NOAA) and were derived from NMFS stock assessments.

Figure 4.4.2: Biomass ratio data are from the NMFS U.S. West Coast Groundfish Bottom Trawl Survey ([http://www.nwfsc.noaa.gov/research/divisions/fram/groundfish/bottom\\_trawl.cfm](http://www.nwfsc.noaa.gov/research/divisions/fram/groundfish/bottom_trawl.cfm)) and were provided by Dr. Todd Hay and Ms. Beth Horness (NOAA).

Figure 4.5.1: California sea lion data were provided by Dr. Sharon Melin (NOAA).

Figure 4.6.1: Seabird abundance data from the Northern CCE were collected and provided by Dr. Jeannette Zamon (NOAA).

Figure 4.6.2: Seabird abundance data from the Southern CCE are from CalCOFI surveys, courtesy of Dr. Bill Sydeman of the Farallon Institute ([wsydeman@faralloninstitute.org](mailto:wsydeman@faralloninstitute.org)).

Figure 5.1.1: Data for commercial landings are from PacFIN (<http://pacfin.psmfc.org>). Data for recreational landings are from RecFIN (<http://www.recfin.org/>).

Figure 5.2.1: Data for total benthic habitat distance disturbed by bottom-contact fishing gears were provided by Mr. Jon McVeigh, NOAA Northwest Fisheries Science Center West Coast Groundfish Observer Program. Weightings for benthic habitat sensitivity values come from PFMC's Pacific Coast Groundfish 5-Year Review of Essential Fish Habitat.

Figure 5.3.1: Shellfish aquaculture production data are from the Washington Department of Fish and Wildlife, Oregon Department of Agriculture and California Department of Fish and Game. The only marine net-pen finfish aquaculture operations in the CCE occur in Washington State, and data came from the Washington Department of Fish & Wildlife.

Figure 5.3.2: Data for total (imported and domestic) edible and nonedible seafood consumption are from NOAA's "Fisheries of the United States" annual reports describing the utilization of fisheries products (<http://www.st.nmfs.noaa.gov/st1/publications.html>).

Figure 6.1.1: Fishery dependence and community social vulnerability index (CSVI) data were provided by Dr. Karma Norman (NOAA) and were derived from the U.S. Census Bureau (<http://www.census.gov>), the American Community Survey (ACS; <https://www.census.gov/programs-surveys/acs/>) and PacFIN (<http://pacfin.psmfc.org>).

Figure 6.1.2: Fishery dependence and community social vulnerability index (CSVI) data were provided by Dr. Karma Norman (NOAA) and were derived from the U.S. Census Bureau (<http://www.census.gov>), the American Community Survey (ACS; <https://www.census.gov/programs-surveys/acs/>) and PacFIN (<http://pacfin.psmfc.org>).

Figure 6.2.1: Fishery diversification estimates were provided by Dr. Dan Holland and Dr. Stephen Kasperski (NOAA).

**APPENDIX C. CHANGES IN THIS YEAR’S REPORT, IN RESPONSE TO COUNCIL AND ADVISORY BODY COMMENTS**

In March 2015, the Council approved FEP Initiative 2, “Coordinated Ecosystem Indicator Review” (Agenda Item E.2.b), by which the Council, advisory bodies, the public, and the CCIEA team would work jointly to refine the indicators in the annual CCIEA Ecosystem Status Report to better meet Council objectives. The Initiative was implemented by an ad-hoc Ecosystem Working Group (EWG). The EWG coordinated several processes by which the CCIEA team was able to receive feedback from Council advisory bodies (including the SSC Ecosystem Subcommittee and several management teams, working groups, subcommittees and panels, including direct meetings in March and September, and also a series of webinars to provide details on key sections of the report. The EWG compiled and provided the collective feedback from these processes. We also received direct feedback from the Council following our presentation to the Council in March 2016.

Below we summarize changes and improvements in the 2017 Ecosystem Status Report, in response to the requests and suggestions received from the Council, EWG and advisory bodies. We will continue to address and integrate requests and suggestions already received, as well as new requests and suggestions in regard to this Ecosystem Status Report.

Request	Response, location in document
Provide maps of sampling locations.	Summary maps are presented in Figure 2.1 (Main Report) for nearly all field sampling.
Continue to focus attention on specific climate events as appropriate (e.g., “The Warm Blob”).	Throughout the Report, we attempt to provide a narrative that links indicators to key climate (and other) drivers.
Provide time series of 3-D temperature information, in addition to sea surface temperature.	Figure 3.1 (Main Report) provides time series of temperature anomalies at depth off Newport, OR and San Diego, CA. Figure E.6 (Appendix E) provides a time series of temperature anomalies at depth averaged over a 10° x 10° area of the Northeast Pacific.
Plot annual and seasonal indicator data in a more consistent manner.	In the Main Report, oceanographic plots (Section 3) and copepod biomass anomaly plots (Section 4.1) contain all data at the finest temporal scale possible. Seasonal averages are presented in Appendix E for oceanographic indicators and Appendix G for copepods.
Provide more specific information in the report on the potential effects of upwelling on particular species (improved productivity, changes in temperature, dissolved oxygen, ocean acidification, etc.).	We have begun to more fully integrate upwelling into the narrative of the document, with specific mention of its broad role in primary production (Main Body, Section 3.2), hypoxia and ocean acidification (Section 3.3, Section 7.6), and forage community dynamics (Section 4.2). We will continue to further integrate this essential ecosystem process, for example how it may relate to ultimate recruitment success for recent year classes of rockfish.

Request	Response, location in document
<p>Present snowpack indicators at regional scales, rather than summarized by the entire system.</p> <p>Include other indicators of freshwater habitat, such as streamflow, at ecologically relevant scales.</p>	<p>Figure 3.4.1 (Main Report) shows snowpack indicators at ecoregional scales (ecoregions mapped in Figure 2.1), and a map of snowpack from 2015-2017 is provided in Appendix F, Figure F.1.</p> <p>Streamflow indicators are plotted at the scale of Chinook salmon ESUs in Figure 3.4.2 (Main Report) and at ecoregional scales in Appendix F.</p>
<p>Present forage indicators by region and individual species, and specify the age classes of the data.</p>	<p>For space considerations, we summarized the status and trends of forage species by region in quad plots in the Section 4.2 of the Main Body. Full time series appear in Appendix G. Age structure is denoted where possible, although this may require further discussion with the SSCES due to our concerns about catchability of juvenile age classes of sardines, anchovy and other fishes.</p>
<p>Make the groundfish biomass and fishing mortality plot larger.</p>	<p>The plot (Figure 4.4.1, Main Body) is now a full page wide.</p>
<p>Include seabird diversity data from the Northern California Current, to accompany the data from the CalCOFI region in the south.</p>	<p>We were unable to obtain full seabird community biodiversity data for either region for this report, but we do have abundance time series for three key seabird species from both regions (Figures 4.6.1 and 4.6.2, Main Body).</p>
<p>Present commercial landings of market squid separately from the rest of the CPS landings.</p>	<p>We now distinguish commercial landings of market squid from the rest of the CPS species at the coastwide level (Figure 5.1.1, Main Body) and at the state-by-state level (Appendix K.1).</p>
<p>Include more information on recreational fishery landings.</p>	<p>In addition to total recreational fishery take (Figure 5.1.1, Main Body), we now include time series of total recreational fishery take (landings + dead discard) from each state (Appendix K.1) and also summarize how that take is distributed across species from different FMPs (Appendix K.2).</p>
<p>Include information on commercial fishing revenues.</p>	<p>We now present time series of commercial fishery revenues by state and by target species groupings (Appendix K.3).</p>
<p>Report gear contact with sea floor by gear type and area.</p>	<p>We developed an index of total fishery gear contact with the seafloor, weighted by total effort by different gear types and by the depths and habitat types in which the gear fished (Main Body, Section 5.2). This index is broken out in more spatial detail in Appendix L. We will do additional analyses to further break it out by specific gear types for future reports.</p>

Request	Response, location in document
Present the community social vulnerability index (CSVI) and the fishery dependence index radar plots at state-level spatial scales.	CSVI scores and fishery dependence indices are broken out into five regions (WA, OR, N CA, Cen CA and So CA) in Appendix N. The ten most commercial fishing-dependent communities are plotted for each region.
Present the community social vulnerability index (CSVI) and the fishery dependence index in x-y space, for ease of interpretation.	The CSVI and fishery dependence index are now plotted in x-y space (Fig. 6.1.2, Main Body), which allows clear distinction of communities that are both highly dependent on commercial fishing and highly social vulnerable.
Include a short section of “Research Recommendations.”	The Main Body ends with Section 7, a list of seven Research Recommendations, with short justifications and proposed products and benefits.
Include a reference section.	Citations of published research now appear throughout the document, and a Reference section is in Appendix P.

## APPENDIX D. CONCEPTUAL MODELS OF THE CALIFORNIA CURRENT

The CCE is a socio-ecological system in which human and naturally occurring components and processes are inextricably linked. Recognizing these links is critical to understanding the dynamics of the CCE and to managing its resources, benefits and services in an informed way. We have developed a series of conceptual models to illustrate these key components, processes and links. The figures below show a series of conceptual models developed specifically for salmon (Fig. D.1) and groundfish (Fig. D.2).

The benefits of conceptual models are multifold:

- They put indicators into context; *each box or line corresponds to one or more indicators.*
- They facilitate discussion around which issues are thought to be most important in the CCE.
- They can be readily simplified or made more in-depth and complex as desired.
- Relating the focal component (e.g., salmon or groundfish) to its linked components and processes may help us anticipate how changes in the ecosystem will affect managed species.
- Conceptual models with up-to-date information on status and trends of relevant indicators could provide information for “ecosystem considerations” sections of stock assessments.
- They serve as consistent reminders to account for human dimensions and potential management tradeoffs in different human sectors.

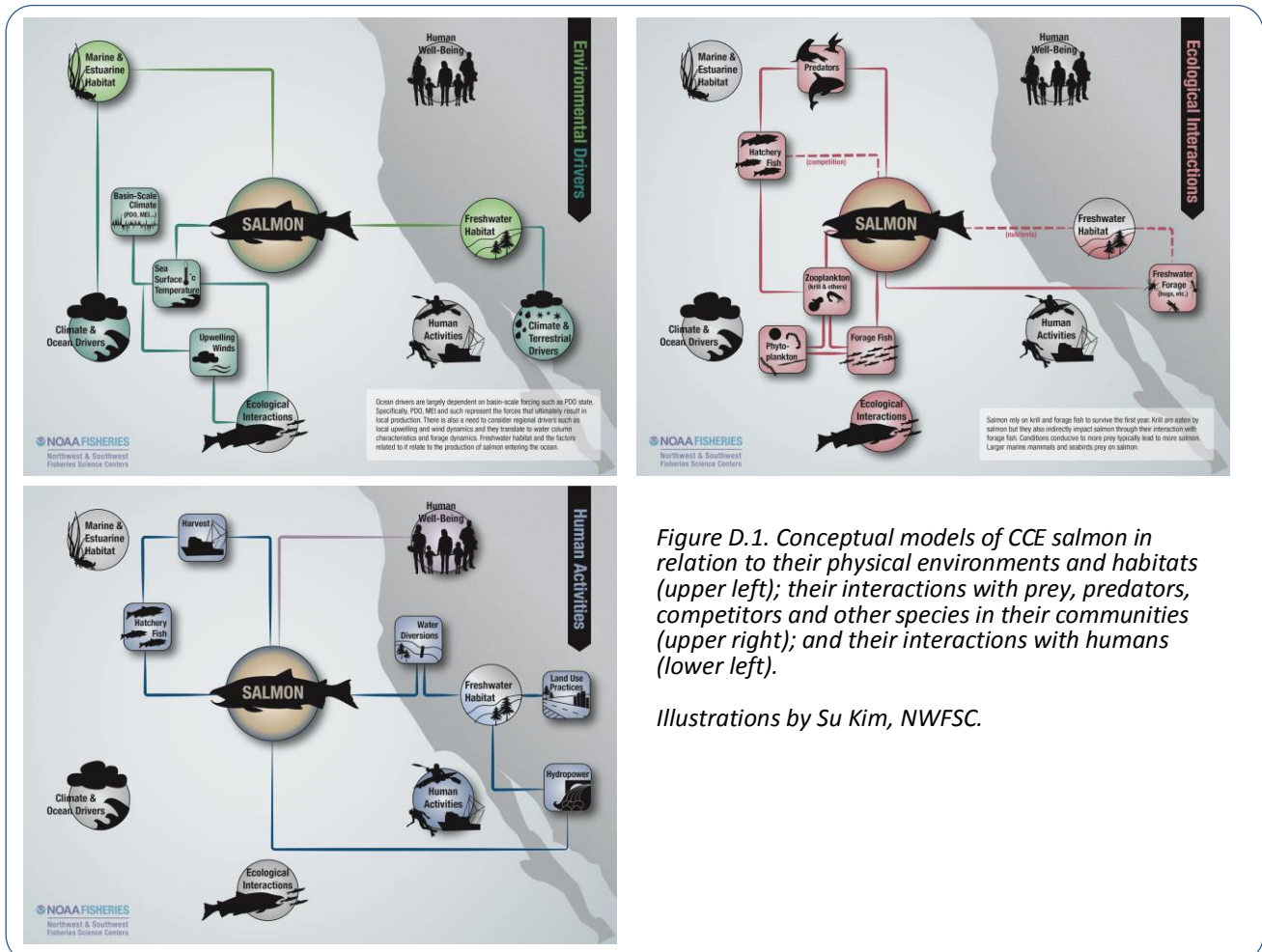


Figure D.1. Conceptual models of CCE salmon in relation to their physical environments and habitats (upper left); their interactions with prey, predators, competitors and other species in their communities (upper right); and their interactions with humans (lower left).

Illustrations by Su Kim, NWFSC.

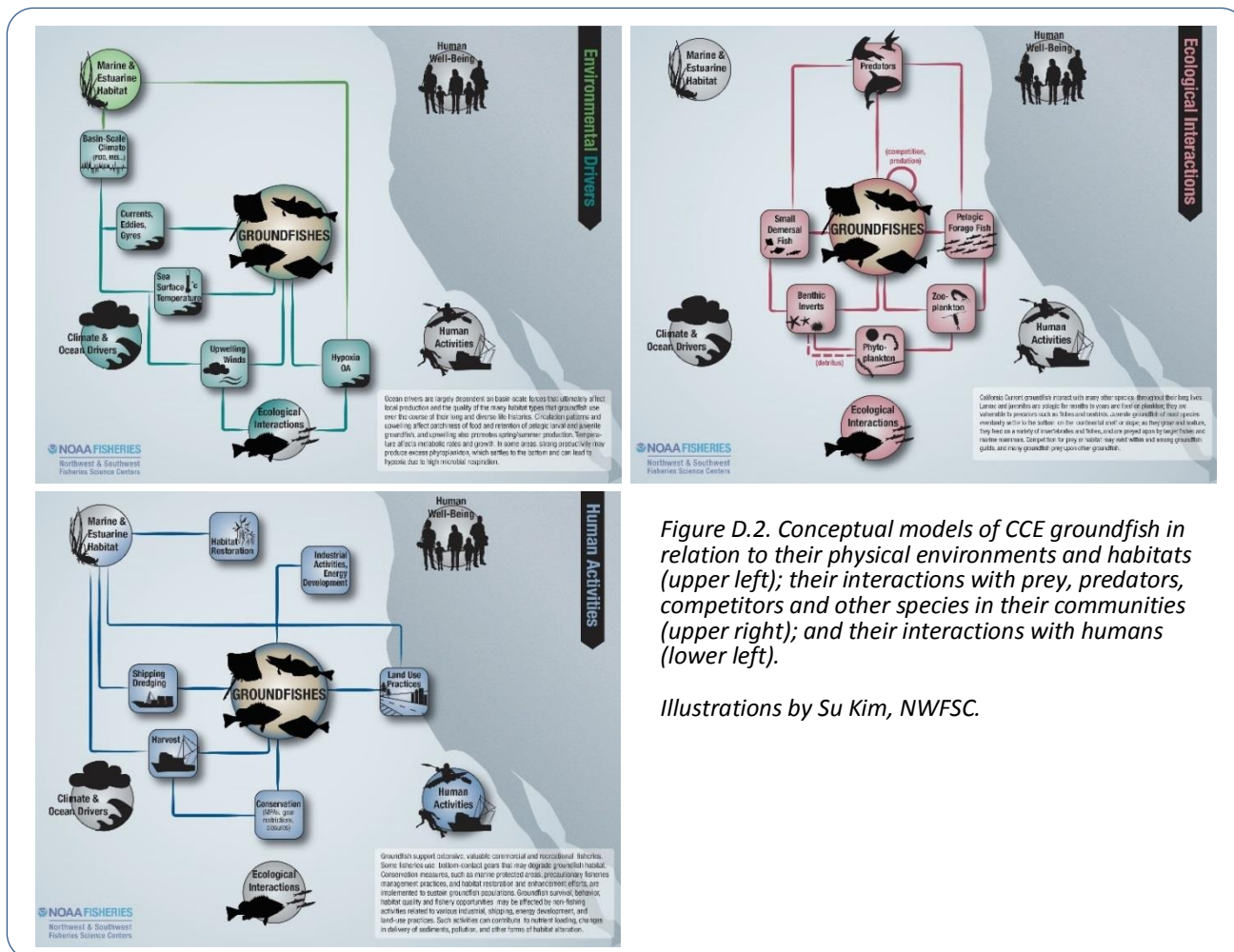


Figure D.2. Conceptual models of CCE groundfish in relation to their physical environments and habitats (upper left); their interactions with prey, predators, competitors and other species in their communities (upper right); and their interactions with humans (lower left).

Illustrations by Su Kim, NWFS.

Similar conceptual models are available for coastal pelagic species, marine mammals, seabirds, habitats, and the full socio-ecological system. For high-resolution versions of all models, please contact Su Kim (Su.Kim@noaa.gov) or Chris Harvey (Chris.Harvey@noaa.gov).

## APPENDIX E. CLIMATE AND OCEAN INDICATORS

Section 3 of the 2017 CCIEA Ecosystem Status Report describes indicators of basin-scale and region-scale climate and ocean drivers. Here we present additional plots to allow a more complete picture of these indicators.

### E1. BASIN-SCALE CLIMATE/OCEAN INDICATORS AT SEASONAL TIME SCALES

The first group of plots in this section shows seasonal summaries of the time series indicators. The final plots are maps of seasonal SST anomalies from 1982-2016.

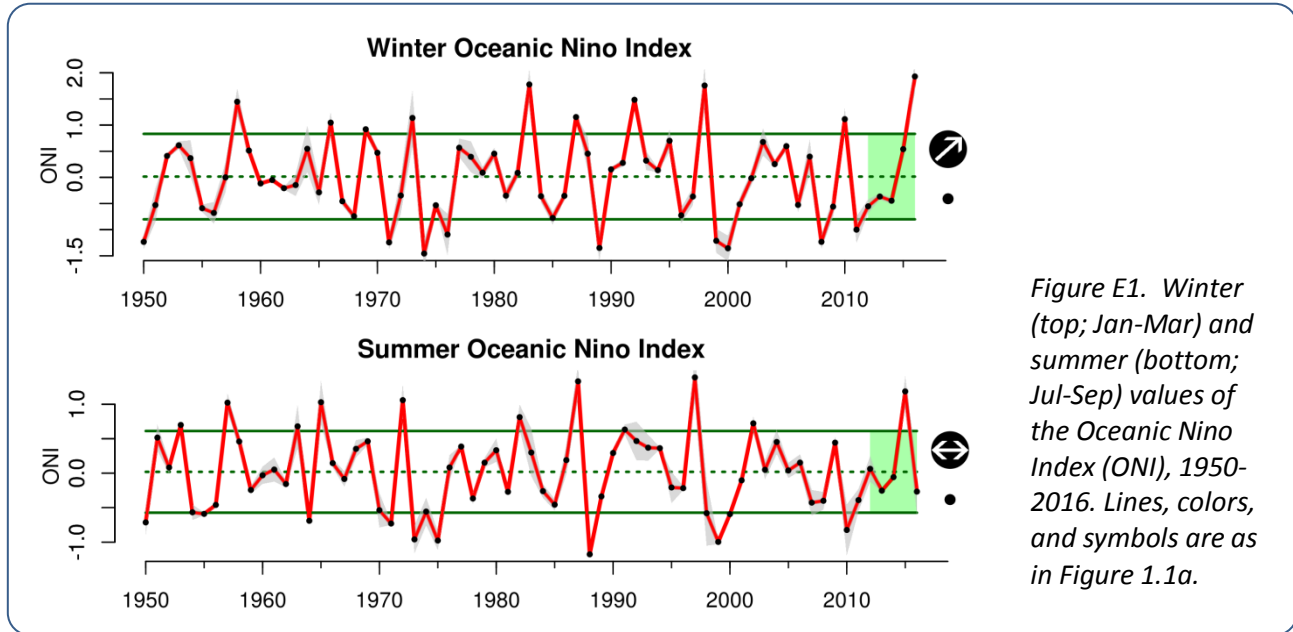


Figure E1. Winter (top; Jan-Mar) and summer (bottom; Jul-Sep) values of the Oceanic Niño Index (ONI), 1950-2016. Lines, colors, and symbols are as in Figure 1.1a.

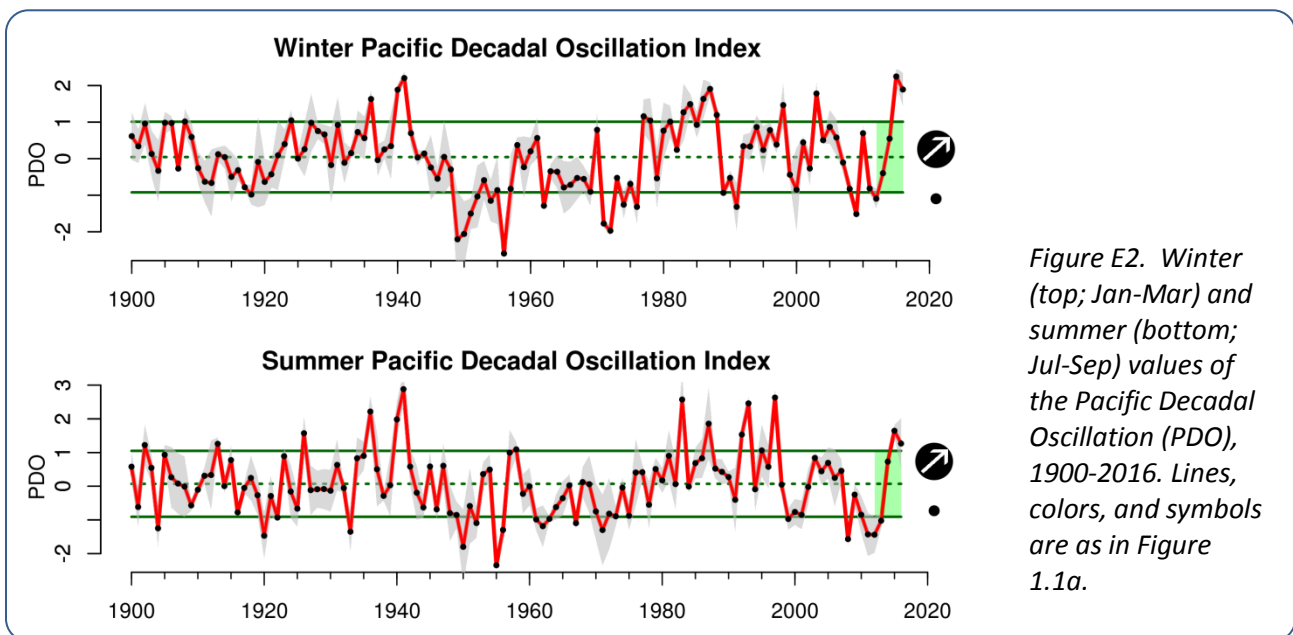
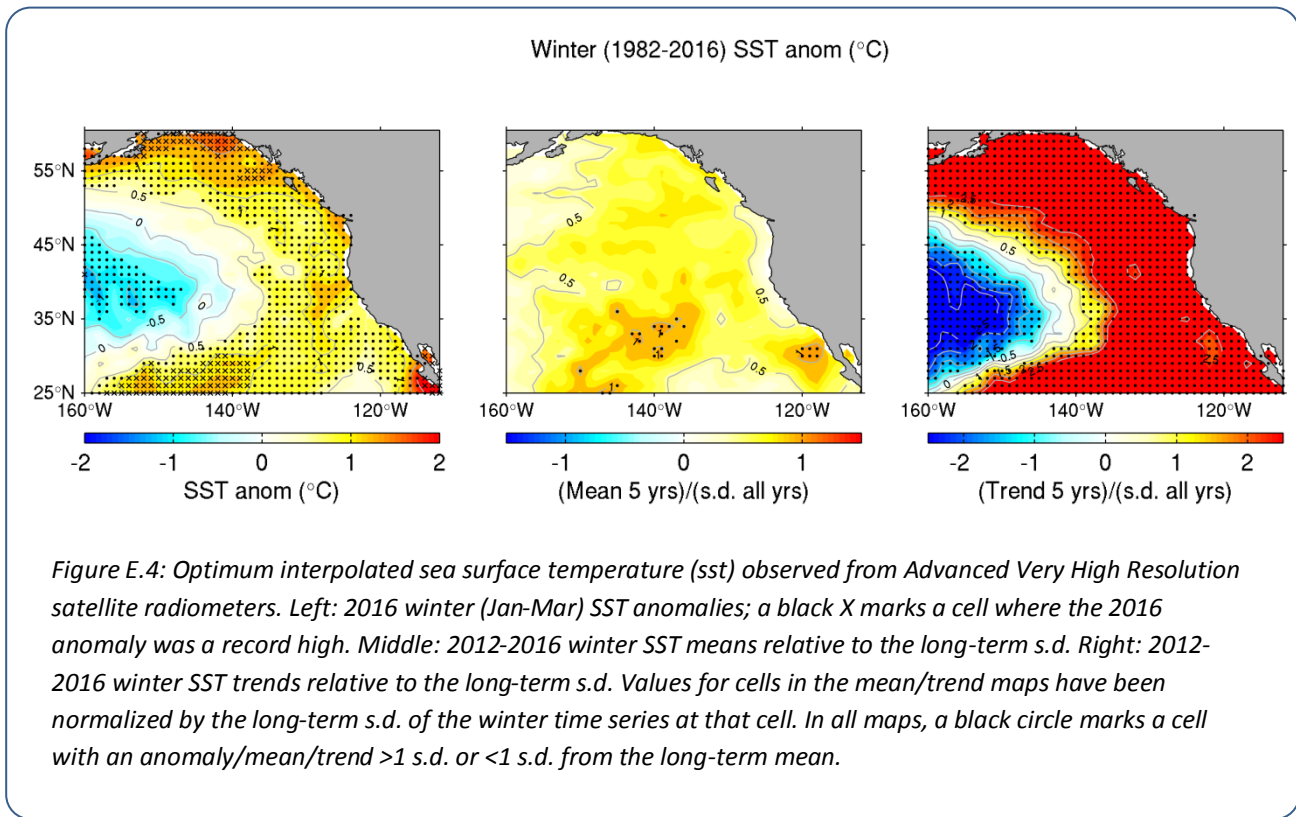
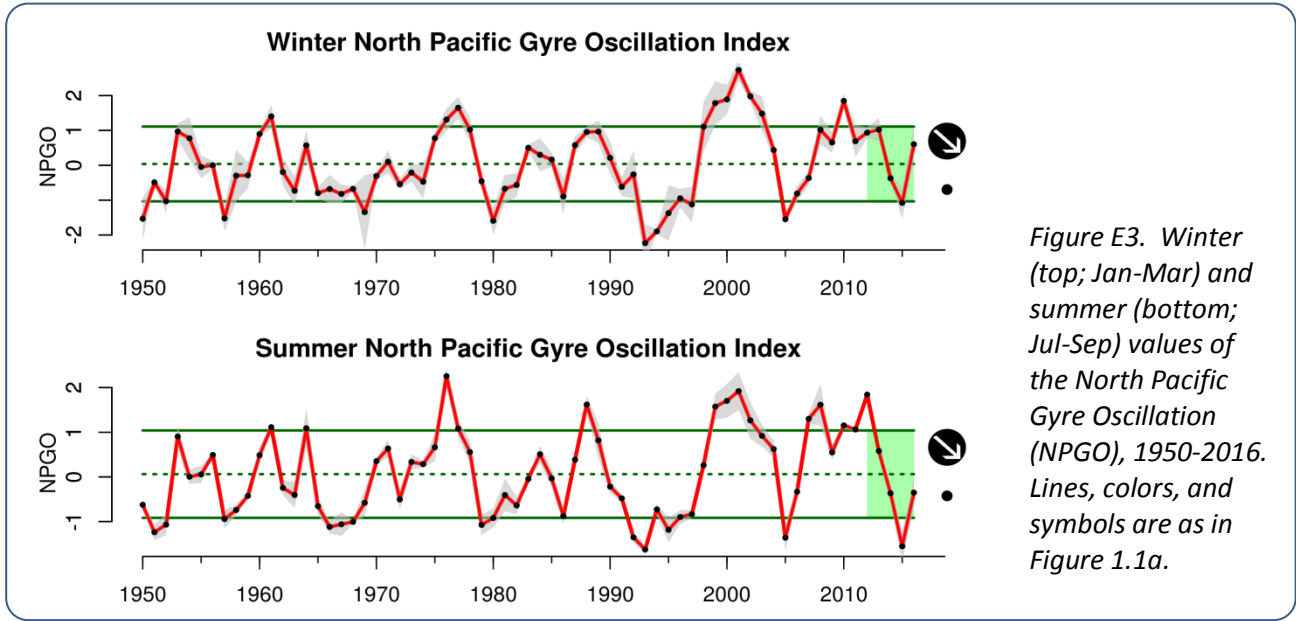


Figure E2. Winter (top; Jan-Mar) and summer (bottom; Jul-Sep) values of the Pacific Decadal Oscillation (PDO), 1900-2016. Lines, colors, and symbols are as in Figure 1.1a.





Summer (1982-2016) SST anom (°C)

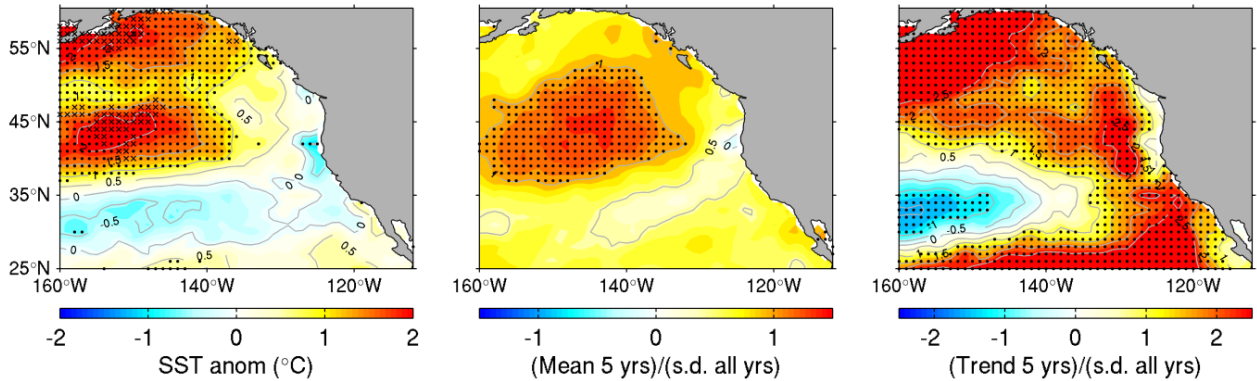


Figure E.5: Optimum interpolated sea surface temperature (sst) observed from Advanced Very High Resolution satellite radiometers. Left: 2016 summer (Jul-Sep) SST anomalies; a black X marks a cell where the 2016 anomaly was a record high. Middle: 2012-2016 summer SST means relative to the long-term s.d. Right: 2012-2016 summer SST trends relative to the long-term s.d. Values for cells in the mean/trend maps have been normalized by the long-term s.d. of the summer time series at that cell. In all maps, a black circle marks a cell with an anomaly/mean/trend  $>1$  s.d. or  $<1$  s.d. from the long-term mean.

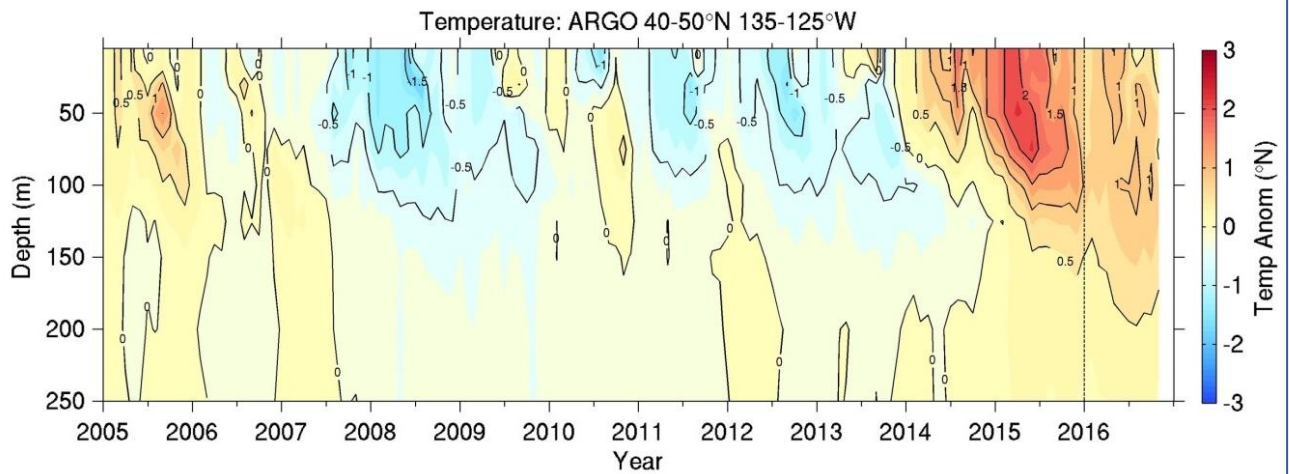


Figure E.6: Time-depth contour of temperature anomalies measured from ARGO floats. The time/depth development of the large marine heat wave and the 2015-2016 El Niño event are noticeable from late 2013 to the end of the 2016 data.

## E2. REGIONAL-SCALE CLIMATE/OCEAN INDICATORS AT SPATIAL AND TEMPORAL SCALES

The plot in this section shows spatiotemporal variation in upwelling intensity and anomalies from 2012-2016.

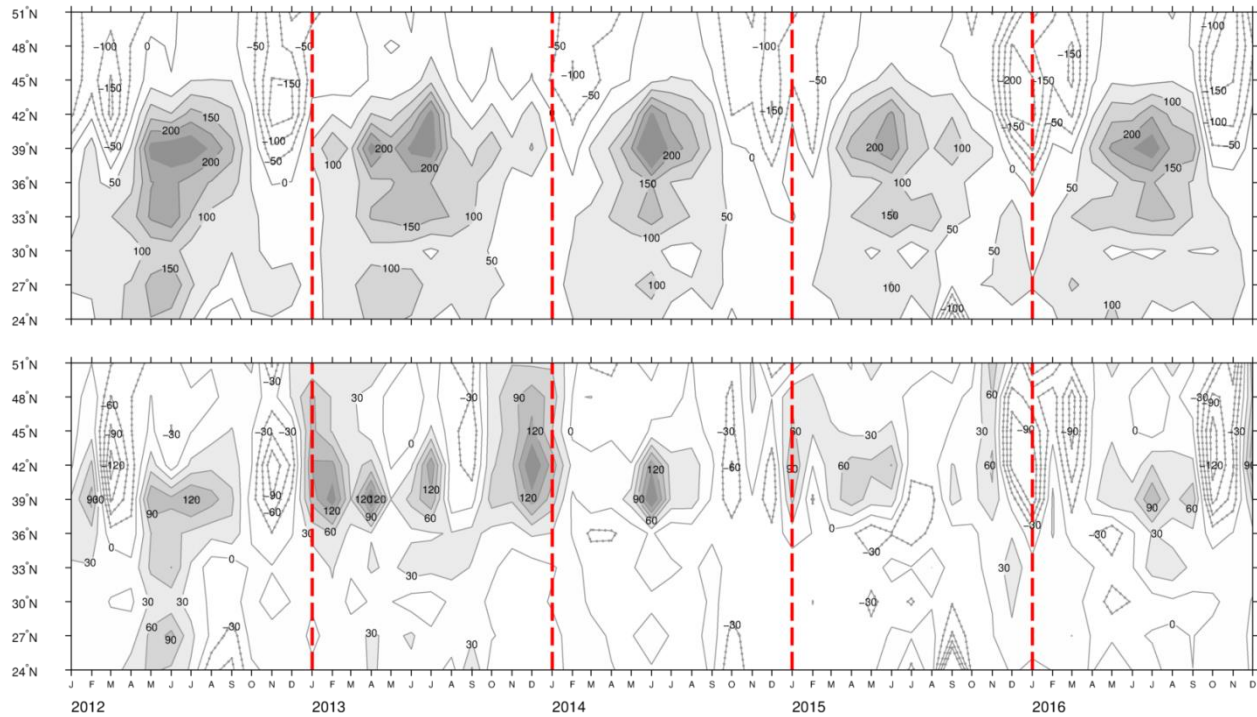


Figure E.7: Monthly means of daily upwelling index (top) and anomalies (bottom) for January 2012–Sep 2016. Shaded areas denote positive (upwelling-favorable) values in upper panel, and positive anomalies (generally greater than normal upwelling) in lower panel. Anomalies are relative to 1967–2015 monthly means. Units are in  $m^3 s^{-1}$  per 100 m of coastline. Daily upwelling index data obtained from <http://upwell.pfeg.noaa.gov/erddap/>.

## E3. SEASONAL TRENDS IN DISSOLVED OXYGEN AND OCEAN ACIDIFICATION INDICATORS

The first series of plots in this section shows time series of summer and winter averages for dissolved oxygen data off Newport, OR and in the Southern California Bight. The second series shows summer and winter averages of aragonite saturation state (an ocean acidification indicator) off Newport.

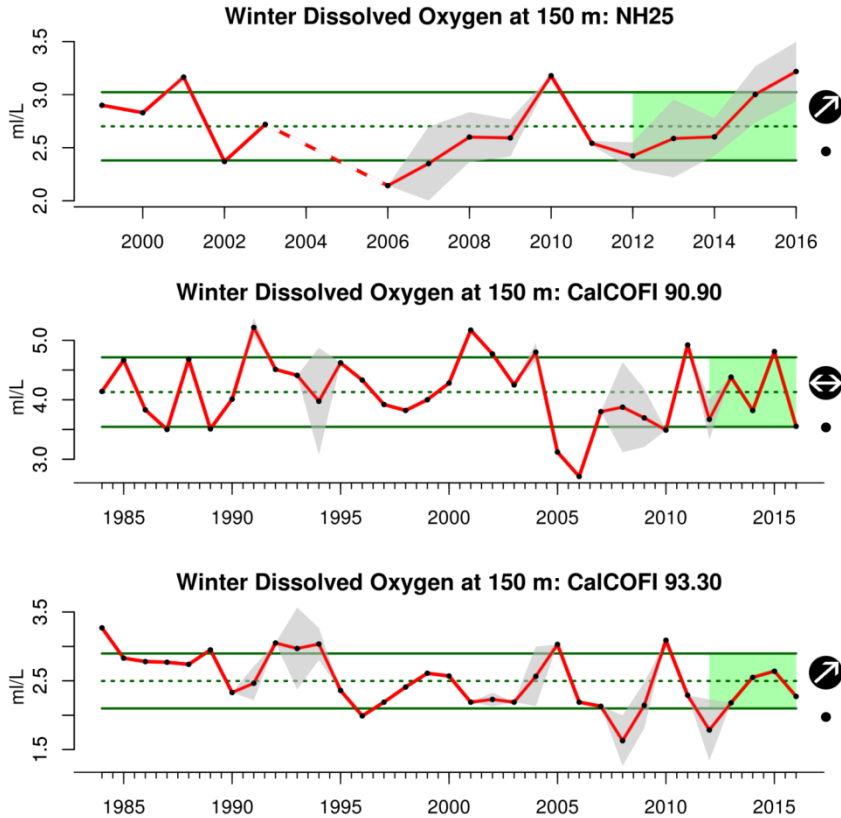


Figure E8. Winter (Jan-Mar) dissolved oxygen (DO) at 150 m depth off Oregon, 1998-2016, and southern California, 1984-2016. Stations NH25 and 93.30 are <50 km from the shore; station 90.90 is >300 km from shore. Lines, colors and symbols are as in Figure 1.1a; dashed red lines indicate missing years.

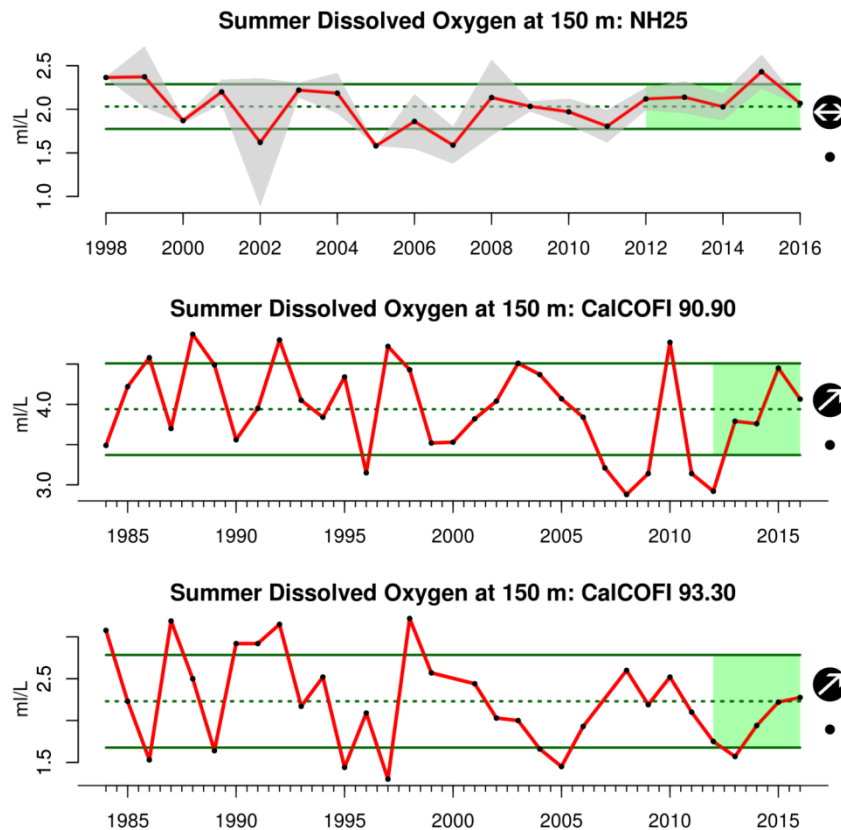
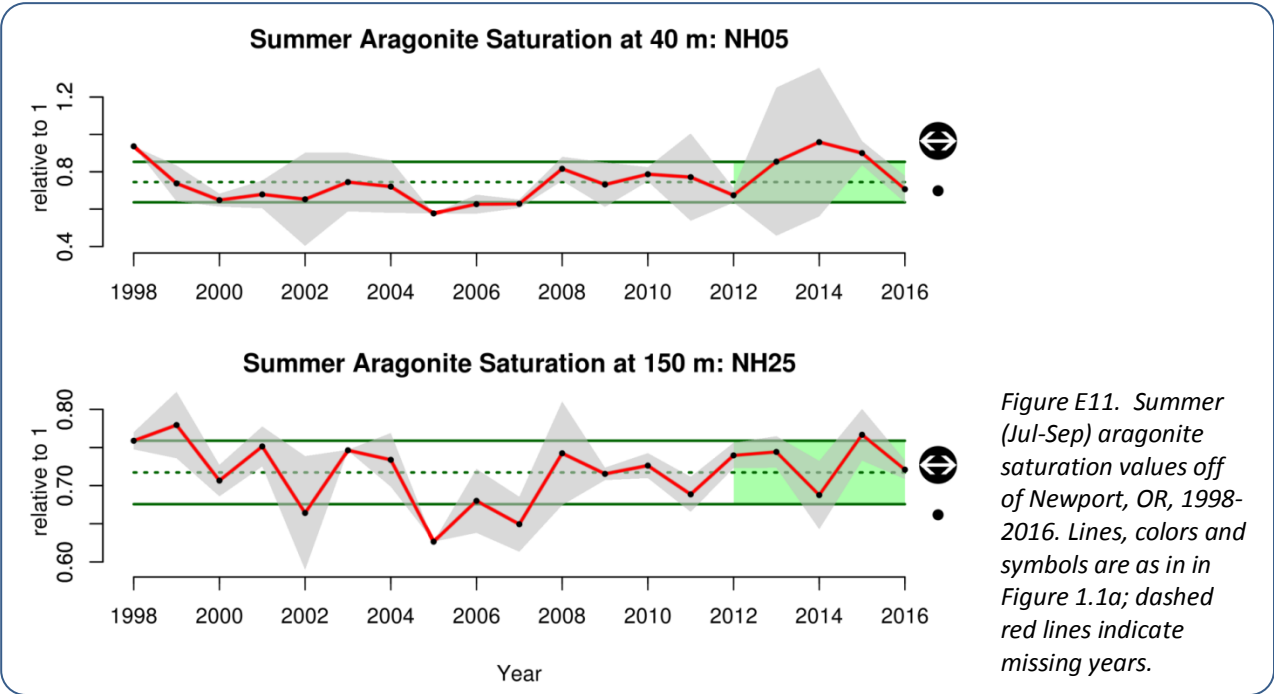
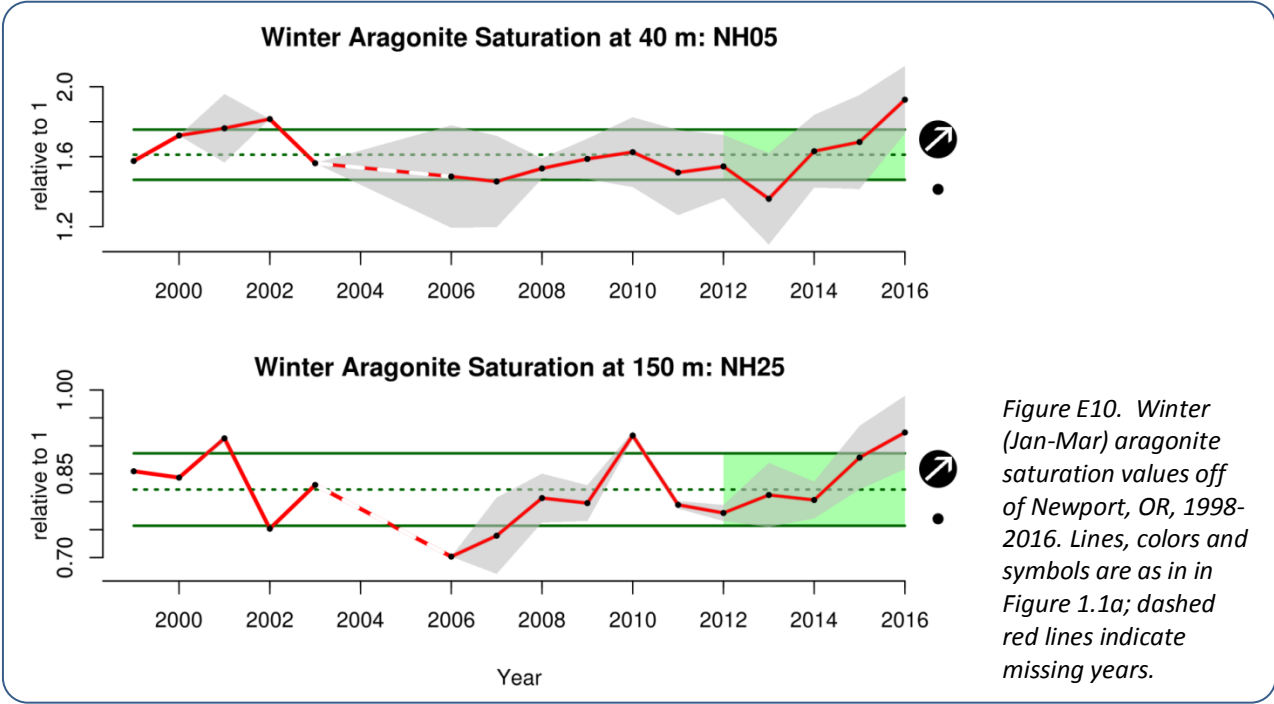


Figure E9. Summer (Jul-Sep) dissolved oxygen (DO) at 150 m depth off Oregon, 1998-2016, and southern California, 1984-2016. Stations NH25 and 93.30 are <50 km from the shore; station 90.90 is >300 km from shore. Lines, colors and symbols are as in Figure 1.1a; dashed red lines indicate missing years.

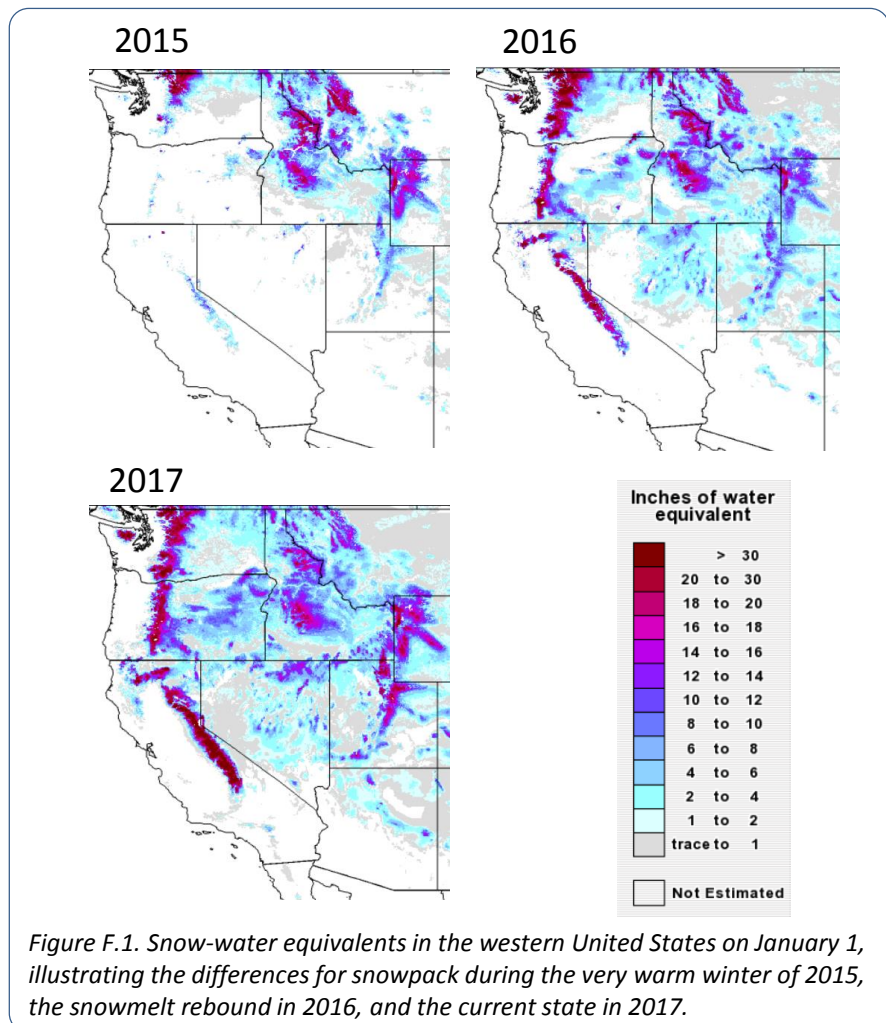


## APPENDIX F. HABITAT INDICATORS: SNOW-WATER EQUIVALENT AND STREAMFLOW

Development of habitat indicators in the CCIEA has focused on freshwater habitats. All habitat indicators are reported based on a hierarchical spatial framework. This spatial framework facilitates comparisons of data at the right spatial scale for particular users, whether this be the entire California Current, ecoregions within these units, or smaller spatial units. The framework we use divides the region encompassed by the California Current ecosystem into ecoregions, and ecoregions into smaller physiographic units. Freshwater ecoregions are based on the biogeographic delineations in Abell et al. (2008; see also [www.feow.org](http://www.feow.org)), who define six ecoregions for watersheds entering the California Current, three of which comprise the two largest watersheds directly entering the California Current (the Columbia and the Sacramento-San Joaquin Rivers). Within ecoregions, we summarized data using 8-field hydrologic unit classifications (HUC-8).

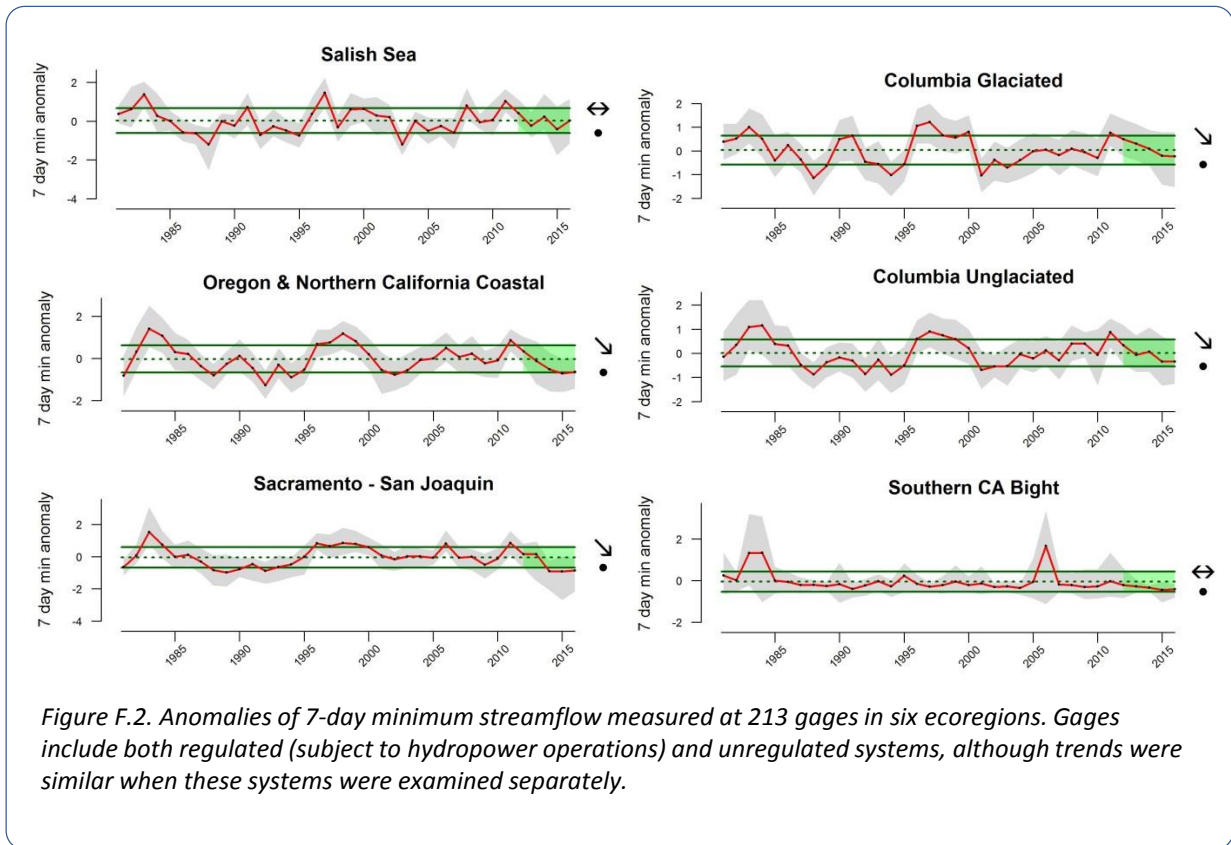
Snow-water equivalent (SWE) is measured using two data sources: a California Department of Water Resources snow survey program (data from the California Data Exchange Center <http://cdec.water.ca.gov/>) and The Natural Resources Conservation Service's SNOTEL sites across Washington, Idaho, Oregon, and California (<http://www.wcc.nrcs.usda.gov/snow/>). Snow data are converted into SWEs based on the weight of samples collected at regular intervals using a standardized protocol. Measurements at April 1 are considered the best indicator of maximum extent of SWE; thereafter snow tends to melt rather than accumulate. Standardized average anomalies of data for each freshwater ecoregion are presented in Section 3.4 of the main report.

The outlook for 2017 is limited to examination of current SWE, an imperfect correlate of SWE in April due to variable atmospheric temperature. Current SWE (on January 1, 2017) exceeds the depth and spatial extent of both 2016 and 2015 (Fig. F.1), which suggests that conditions may be better this year compared to the previous two years.



Streamflow is measured using active USGS gages (<http://waterdata.usgs.gov/nwis/sw>) with records that meet or exceed 30 years in duration. Average daily values from 213 gages were used to calculate both annual 1-day maximum and 7-day minimum flows. These indicators correspond to flow parameters to which salmon populations are most sensitive. Standardized anomalies of time series from individual gages were then averaged to obtain weighted averages for ecoregions (for which HUC-8 area served as a weighting factor) and for the entire California current (weighted by ecoregion area).

Across the California Current, both minimum and maximum streamflow anomalies have exhibited strong variability in the most recent five years. Minimum streamflows have exhibited fairly consistent patterns across all ecoregions (Fig. F.2). Most all ecoregions demonstrated a decline in low flows over the last 5-8 years, although little variation exists for rivers in the Southern California Bight. For maximum streamflows (Fig. F.3), 5-year trends were particularly pronounced for the Salish Sea and Washington Coast (increased high flows) and the Southern California Bight (high flows were historically low).



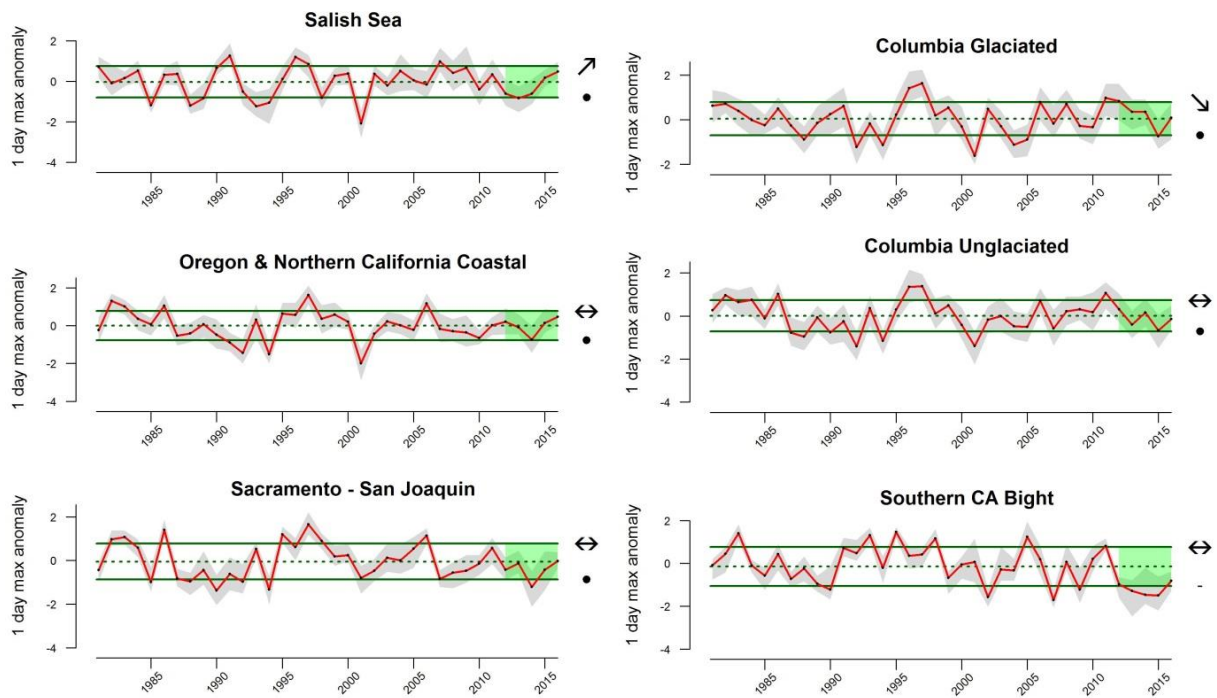


Figure F.3. Anomalies of 1-day maximum annual streamflow measured at 213 gages in six ecoregions. Gages include both regulated (subject to hydropower operations) and unregulated systems, although trends were similar when these systems were examined separately.



## APPENDIX G. REGIONAL FORAGE AVAILABILITY

Species-specific trends in forage availability are based on research cruises in the northern, central, and southern portions of the CCE (Fig. 2.1c). Section 4.2 of the main body of this report describes forage community dynamics using quad plots to summarize recent status and trends relative to full time series. These plots are useful for summarizing large amounts of data, but they may hide informative short-term variability in these dynamic species. The full time series through 2016 are therefore presented here. As noted in the main report, we consider these to be regional indices of relative forage availability and variability; these are not indices of absolute abundance of coastal pelagic species (CPS). Collection details and format are indicated in the respective figure legends.

### G.1. NORTHERN CALIFORNIA CURRENT FORAGE

The Northern CCE survey (known as the “BPA Plume Survey”) occurs in June and targets juvenile salmon in surface waters off Oregon and Washington, but also collects adult and juvenile (age 1) pelagic forage fishes, market squid, and gelatinous zooplankton (*Aequorea* sp., *Chrysaora* sp.) with regularity. In 2016, most forage taxa were caught at levels within the long-term range of the survey (Fig. G.1). One exception was jack mackerel catch, which exceeded long-term averages for the second year in a row. Catches of both age 1+ sardine and age 1+ anchovy were relatively poor, with sardine only captured at a single station. Catch rates of both gelatinous zooplankton taxa in 2016 were below or near long term averages, reflecting a decline from 2015 levels for *Aequorea* sp.

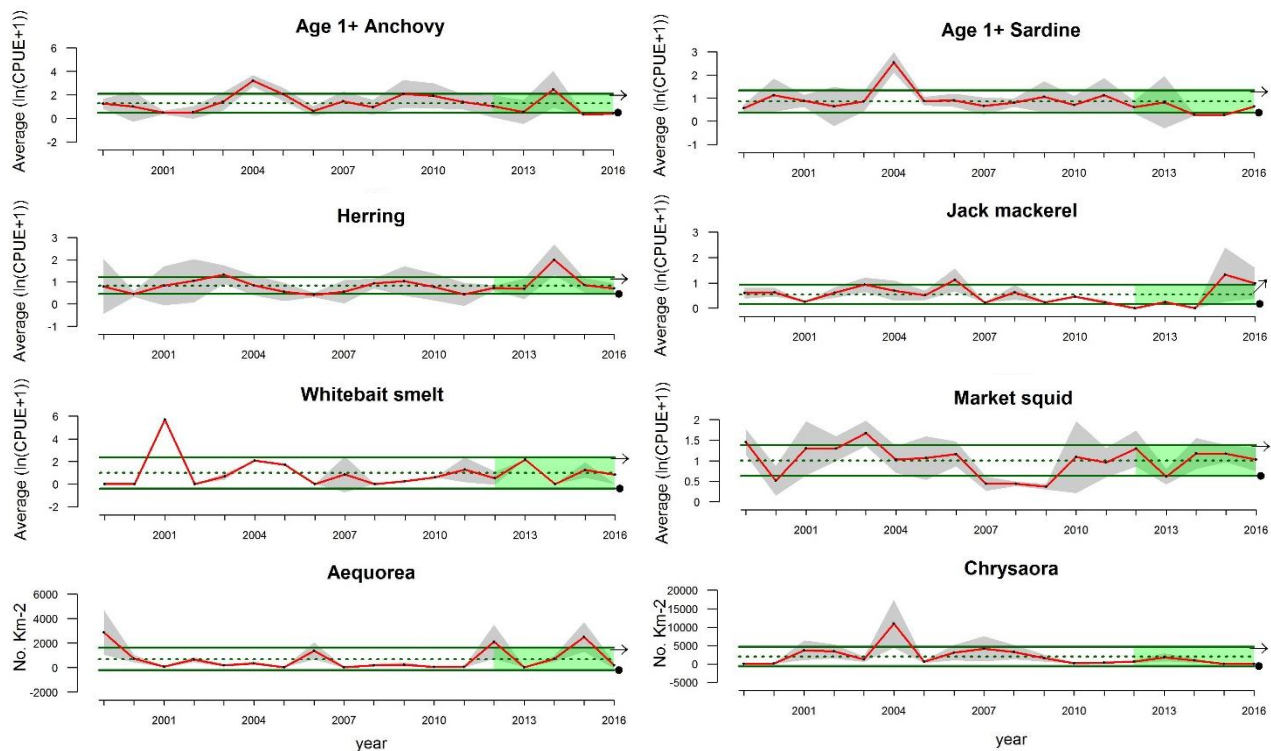


Figure G.1. Geometric mean CPUEs ( $\#/km^2$ ) of key forage groups in the Northern CCE, from surface trawls conducted as part of the BPA Plume Survey, 1999-2016. Lines, colors and symbols are as in Figure 1.1a. Note different units for gelatinous zooplankton data (bottom row).

## G.2. CENTRAL CALIFORNIA CURRENT FORAGE

The Central CCE forage survey (known as the “Juvenile Rockfish Survey”) samples this region using midwater trawls, which not only collect young-of-the-year (YOY) rockfish species, but also a variety of other YOY and adult forage species, market squid, adult krill, and gelatinous zooplankton. Time series presented here are from the “Core Area” of that survey (see Fig. 2.1c in the Main Report). In 2016, catches of adult anchovy and sardine remained near zero, whereas YOY rockfish, YOY hake and YOY sanddabs continued recent patterns of exceptionally high catch (Fig. G.2). (Note: YOY anchovy and sardine are not included in the data below.) Market squid catches declined into 2016, while krill returned to near the long-term mean after a steep decline in 2015. Finally, two jellyfish taxa (*Aurelia* sp., *Chrysaora*) enumerated over most of this survey appeared to show average to below-average catch rates, although these signals may actually be masked by abandonment of tows at stations where exceptional catches of jellyfish and tunicates (pyrosomes and salps, not presented here) have clogged survey nets in the past.

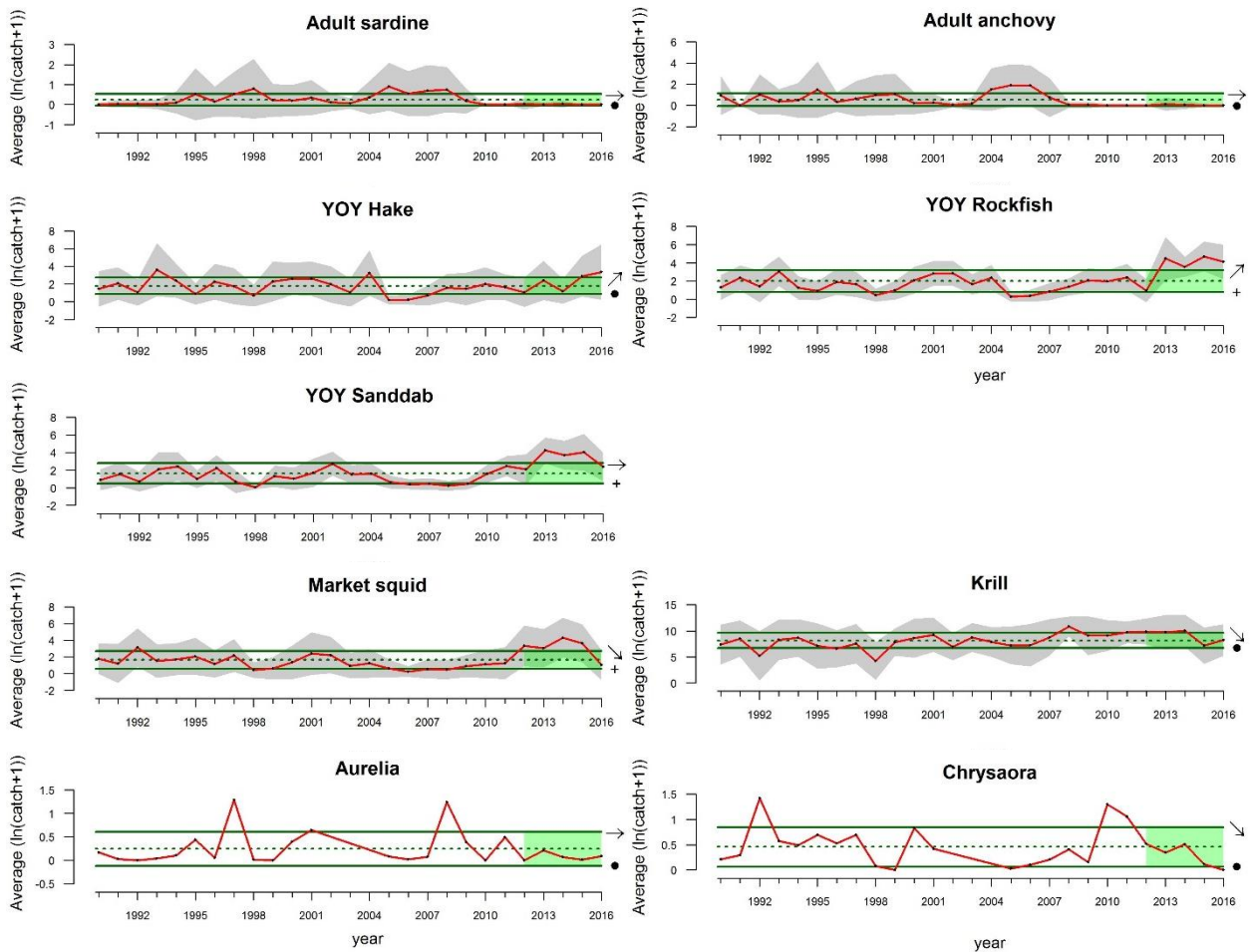


Figure G.2. Geometric mean CPUEs (#/15 min haul) of key forage groups in the Central CCE, from the SWFSC Rockfish Recruitment and Ecosystem Assessment Survey during 1990-2016. Lines, colors and symbols are as in Figure 1.1a, with the exception that shaded errors in these figures represent standard deviations of log transformed catches; no errors presented for gelatinous zooplankton spp. (bottom figures).

### G.3. SOUTHERN CALIFORNIA CURRENT FORAGE

The abundance indicators for forage in the Southern CCE come from fish and squid larvae collected in the spring across all core stations of the CalCOFI survey using oblique vertical tows of fine mesh Bongo nets to 212 m depth. The survey collects a variety of fish and invertebrate larvae (<5 d old) from several taxonomic and functional groups. Larval data are indicators of the spawning stock biomass of forage species such as anchovy and sardine. They likely also reflect the relative abundance of some other fish species, including mesopelagic species. At the time of this report, samples from 2016 have been processed and enumerated for only the four taxa presented below; other species groups (e.g., shortbelly rockfish, myctophids) are forthcoming. Noteworthy observations from 2016 surveys include the increase in relative abundance of anchovy, the total absence of sardine in all survey tows, and the decline of hake and market squid (Fig. G.3).

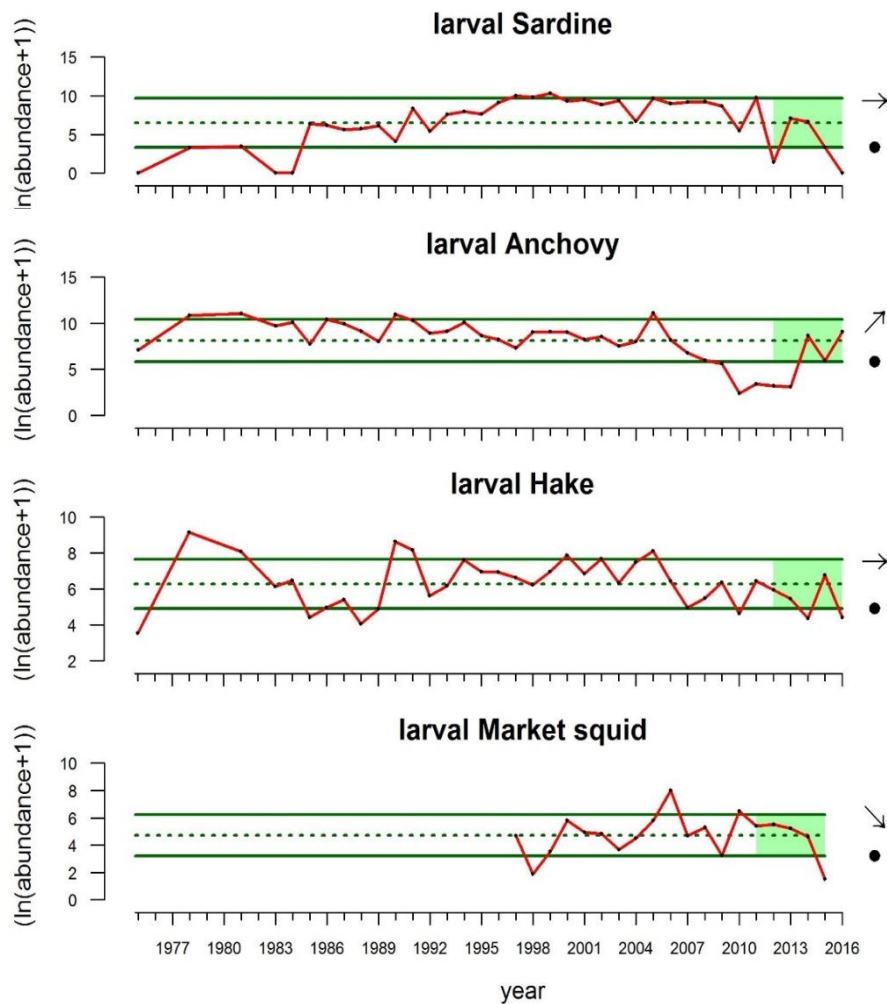


Figure G.3. Average larval abundance ( $\ln(\text{abundance}+1)$ ) of key forage species in the Southern CCE, from spring CalCOFI surveys during 1975-2016. Lines, colors and symbols are as in Figure 1.1a.

## APPENDIX H: CHINOOK SALMON ESCAPEMENT INDICATORS

Population-specific status and trends in Chinook salmon escapement are provided in Section 4.3 of the Main Report. Figure 4.3.1 uses quad plots to summarize recent escapement status and trends relative to full time series. These plots are useful for summarizing large amounts of data, but they may hide informative short-term variability in these dynamic species. The full time series for all populations are therefore presented here. We note again that these are escapement numbers, not run-size estimates, which take many years to develop. Status and trends are estimated for the most recent 10 years of data (unlike 5 years for all other time series in this Report) in order to account for the spatial segregation of successive year classes of salmon.

### H.1. CALIFORNIA CHINOOK SALMON ESCAPEMENTS

The Chinook salmon escapement time series from California include data from as recent as 2015 extending back over 20 years, with records for some populations (Central Valley Late Fall; Southern Oregon/Northern California Coastal; Klamath Fall) stretching back to the 1970s. Most near-term trends showed no trend, with the exception of Central Valley Winter Chinook, which reflected a declining escapement trend that is due to the very influential point from the relatively large escapement in 2006 (Fig. H.1). Escapement estimates for all populations in 2015 were below the long-term mean for their respective time series, and many populations have experienced decreasing escapements from 2013-2015 after some increases in the preceding years.

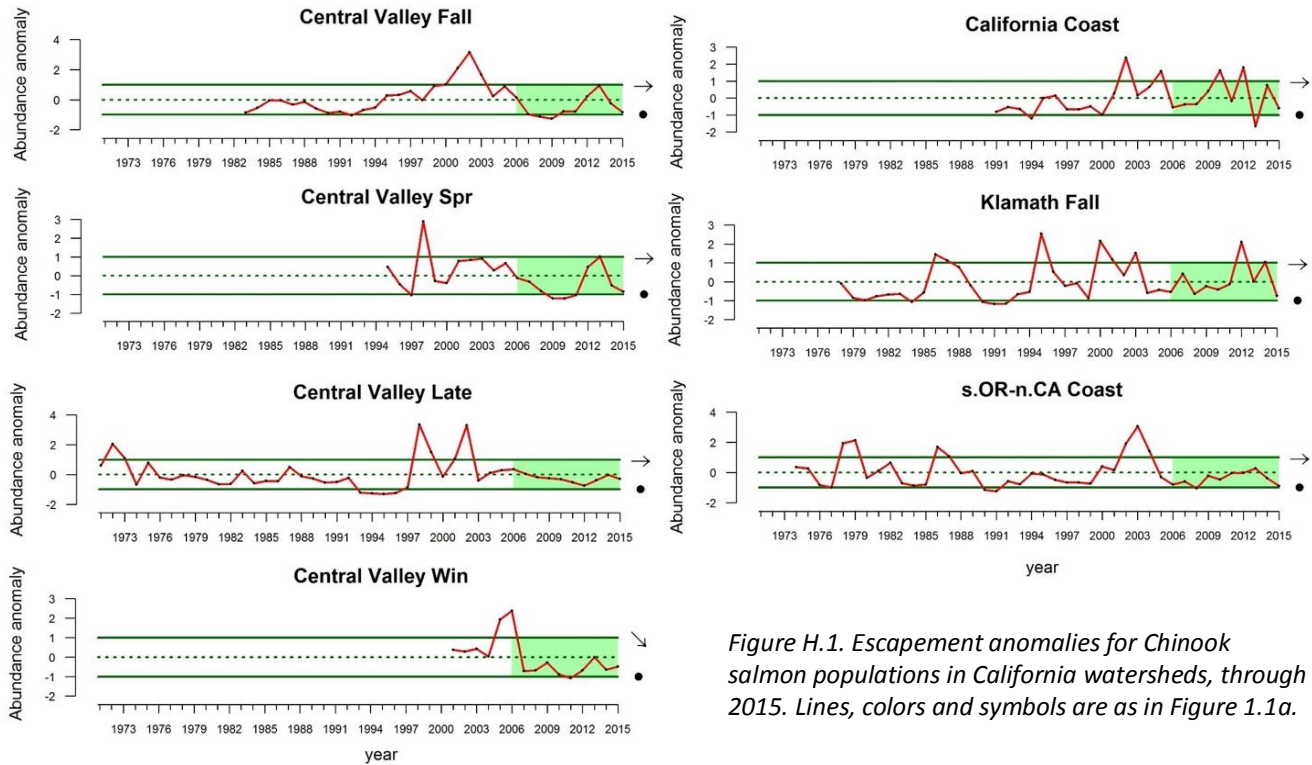


Figure H.1. Escapement anomalies for Chinook salmon populations in California watersheds, through 2015. Lines, colors and symbols are as in Figure 1.1a.

## H.2. WASHINGTON/OREGON/IDAHO CHINOOK SALMON ESCAPEMENTS

The escapement time series used for Chinook salmon populations from Washington, Idaho, and Oregon extend back over 40 years, but because the stocks are often co-managed and the surveys conducted by a variety of state and tribal agencies, the most recent data are currently only available through 2014 (Fig. H.2). Three of five stocks have shown improving escapement trends in the last ten years, including both Snake River populations and the Lower Columbia populations. Snake River Fall Chinook in 2014 were at their highest level of the time series, and the recent average is significantly greater than the long-term mean. Other populations' recent averages are within 1 s.d. of long-term means.

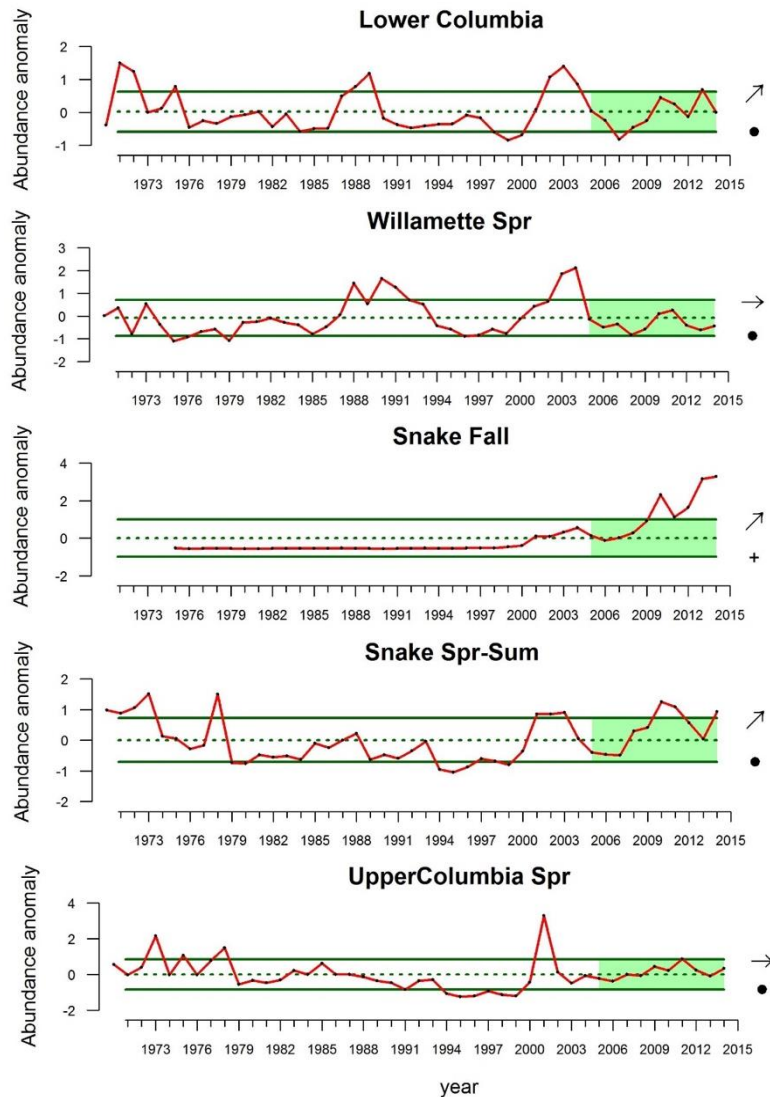


Figure H.2. Escapement anomalies for Chinook salmon populations in Washington/Oregon/Idaho watersheds, through 2014. Lines, colors and symbols are as in Figure 1.1a.

## APPENDIX I: DEMERSAL COMMUNITY STRUCTURE

We are tracking the abundance of groundfish relative to Dungeness and Tanner crabs as a metric of seafloor community structure and trophic status. It may also relate to opportunities for vessels to participate in different fisheries.

Data are area-weighted mean crab:finfish biomass ratios from NMFS trawl survey sites north and south of Cape Mendocino (Fig. I.1). The ratio has varied by region and time, and peaked in the south in 2010, a year earlier than in the north. Following those peaks, the crab:finfish ratio declined, but increases in 2015 stabilized the recent trend in the south.

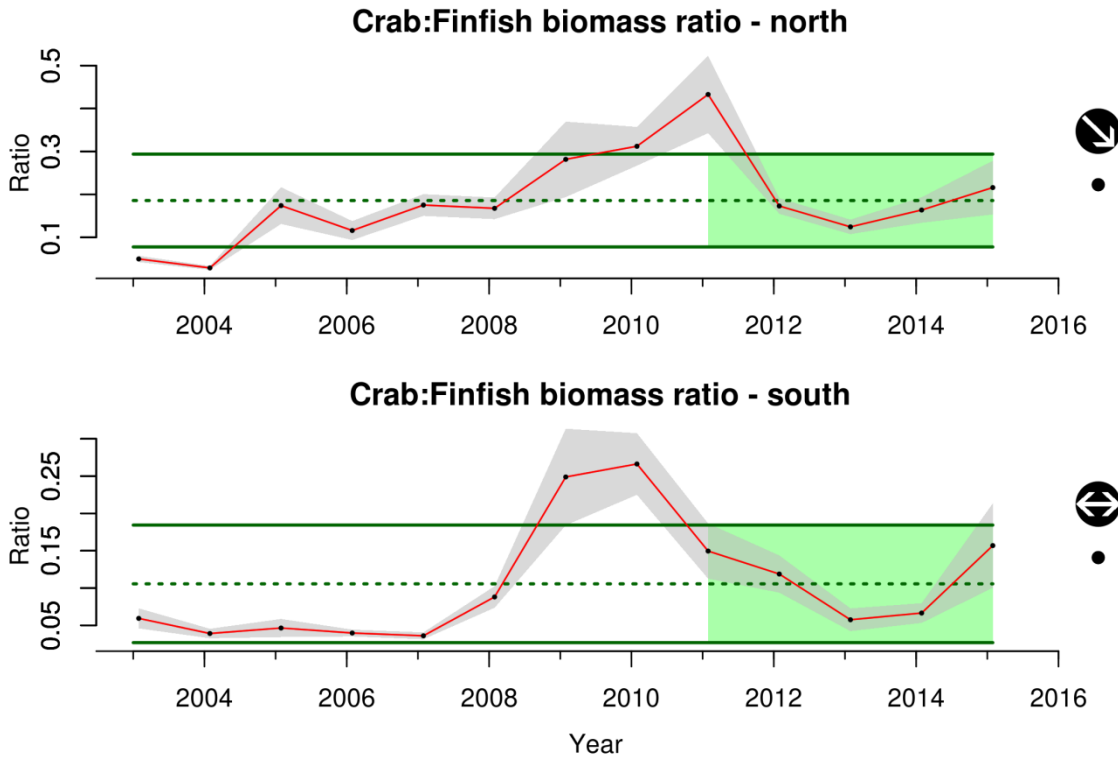


Figure I.1: Ratio of crabs to finfish biomass from the NMFS West Coast Groundfish Bottom Trawl Survey through 2015. Lines, colors and symbols are as in Fig. 1.1a.

## APPENDIX J. THE 2016 RHINOCEROS AUKLET MORTALITY EVENT

In 2016, elevated numbers of rhinoceros auklets washed up on beaches in the northern CCE. The timing of this “wreck” of dead birds was atypical, as the mortality pulse began during the summer/fall breeding season, rather than the post-breeding period when mortalities often are observed. The density of dead rhinoceros auklets in the summer months reached ~70 times normal in the Salish Basin, ~50 times normal in the Western Strait of Juan de Fuca, ~20 times normal along the northern and southern Washington coast, and ~4 times normal along the northern Oregon coast (Fig. J.1). Mortalities in southern Oregon and northern California in 2016 were at or below the long-term average.

The breeding season signal was picked up via colony monitoring as well. On Protection Island in Puget Sound, egg-laying and hatching success (# chicks/egg) did not differ from past years, but chick growth was delayed and fledging success (# fledglings/egg) was the lowest seen in a decade of monitoring. Causes apart from productivity, such as harmful algal blooms or avian influenza, have not been identified. The auklet carcasses showed signs of emaciation, and some showed indications of bacterial infection; however assigning causation to either of those factors has not been possible.

Rhinoceros auklet mortality has been observed in past warm-water years, particularly in El Niño events, but are were largely confined to the post-breeding period. The mechanisms for these continuing events (the Cassin’s auklet wreck in 2014 and common murre wreck in 2015) may be linked to warm ocean conditions arose in this region in late 2014 and continued into 2016. Rhinoceros auklets are primarily piscivores like common murre, while Cassin’s auklets are planktivores. Given the likely connection of these die-offs to the ecosystem state, explorations of forage availability and condition as well as foraging patterns by these upper-trophic-level consumers are warranted.

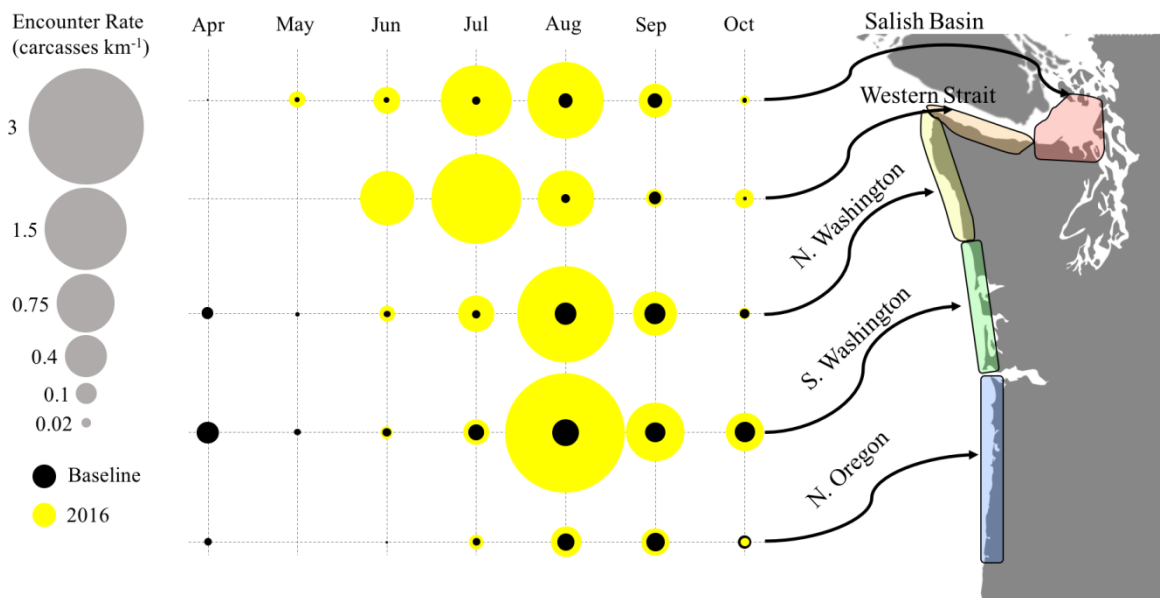


Figure J.1. Rhinoceros auklet mortality (carcasses/km) along beaches in the northern CCE. Circle diameters are proportional to long-term baseline (black) and 2016 (yellow) by month

## APPENDIX K. STATE-BY-STATE FISHERY LANDINGS AND REVENUES

The Council and the EWG have requested information on state-by-state landings and revenues from fisheries, including recreational fishing; these values are presented here. Fishery removal data are derived from assessments for species assessed through 2015; the Pacific Fisheries Information Network (PacFIN, <http://pacfin.psmfc.org>) for commercial landings; and the Recreational Fisheries Information Network (RecFIN, <http://www.recfin.org>) for recreational landings. Landings provide the best long-term indicator of fisheries removals. The best information on revenue is also summarized in PacFIN. Revenue was calculated based on consumer price indices for 2015.

### K.1. STATE-BY-STATE LANDINGS

Total fisheries landings in California decreased over the last five years and these patterns were driven almost completely by decreases in landings of market squid (Fig. K.1). Landings of groundfish (excluding hake), CPS (excluding squid) and recreationally caught species have been consistently at historically low levels over the last five years, while landings of crab decreased greatly in 2015 from historically high levels over the same period. Landings of shrimp, salmon and HMS have been relatively unchanged over the last five years.

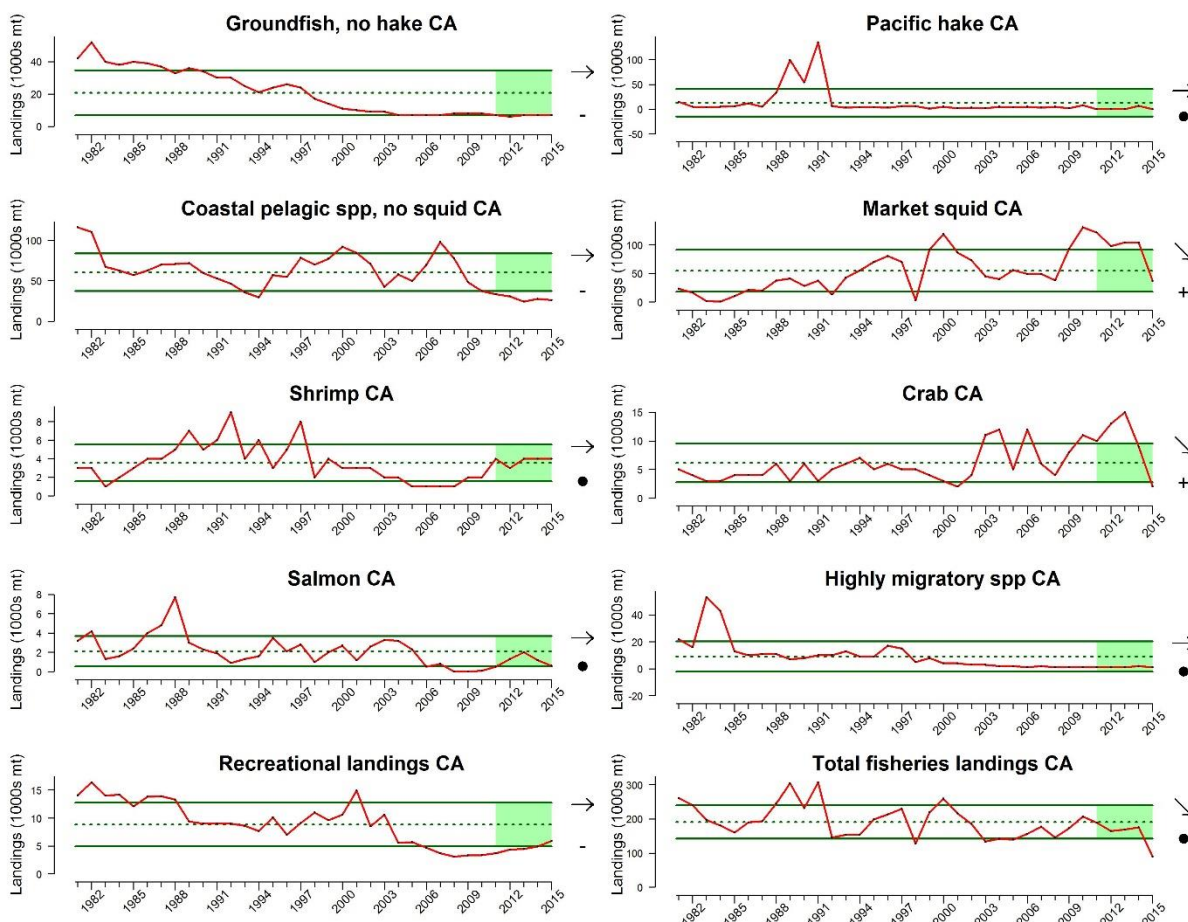


Figure K.1. Annual landings of commercial (data from PacFIN and NORPAC) and recreational fisheries (data from RecFIN), including total landings across all fisheries from 1981-2015 in California (CA). Lines and symbols are as in Figure 1.1a.



Total fisheries landings in Oregon have varied widely with historically high levels of landings and a relatively large decrease in landings within the last five years (Fig. K.2). These patterns were driven by interactions in landings of Pacific hake, which have varied over the last five years, and coastal pelagic species (excluding squid) and crab, which have both decreased over the last five years. Landings of groundfish (excluding hake) have been consistently near historically low levels, while landings of shrimp were at historically high levels over the last five years. Landings of highly migratory species and salmon have been within historical averages over the last five years.

In contrast to commercial fisheries landings, recreational fisheries landings in Oregon have increased over the last five years. Neither of the other states experienced an increase in recreational fishing in recent years.

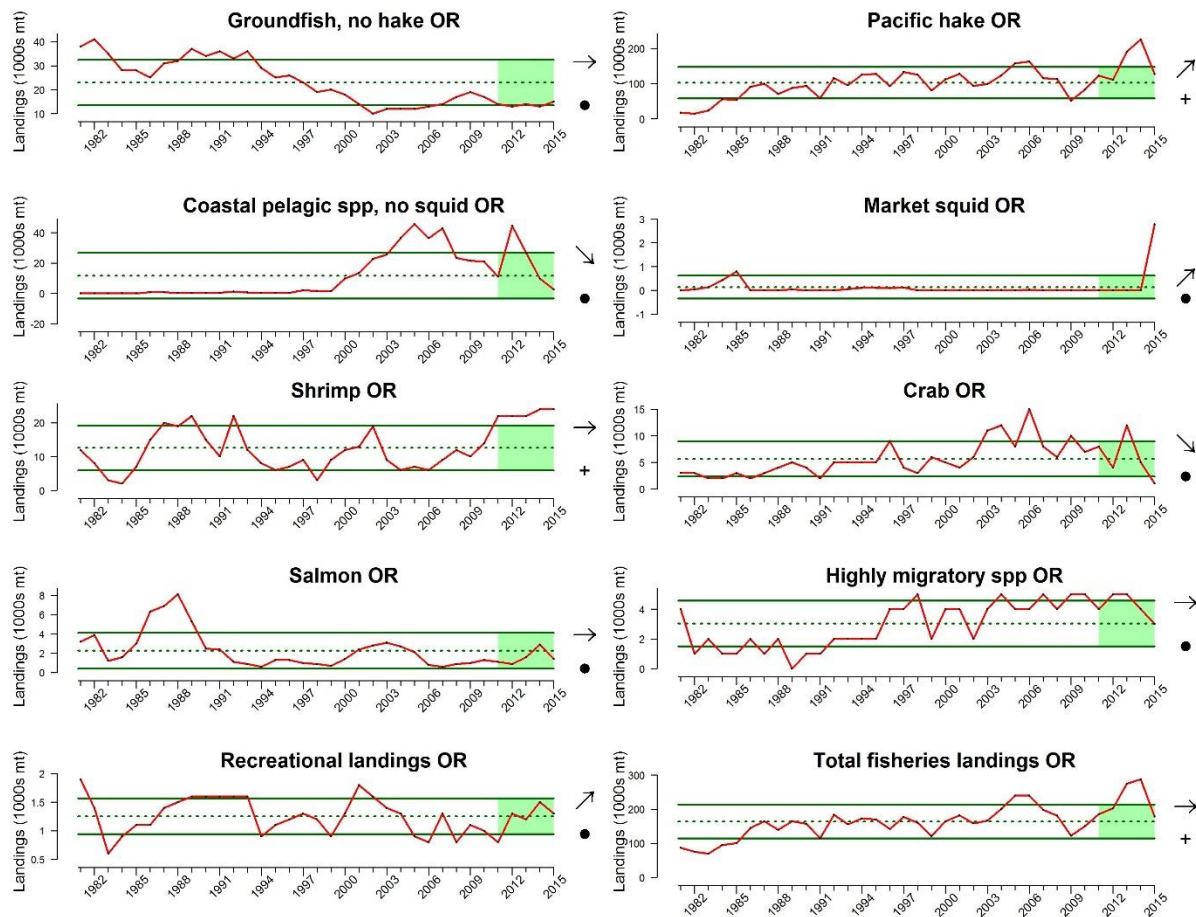


Figure K.2. Annual landings of commercial (data from PacFIN and NORPAC) and recreational fisheries (data from RecFIN), including total landings across all fisheries from 1981-2015 in Oregon (OR). Lines and symbols are as in Figure 1.1a.

Total fisheries landings in Washington decreased over the last five years, with particularly low landings in 2015 (Fig. K.3). These patterns were driven primarily by large decreases in the landings of Pacific hake and coastal pelagic species (excluding squid) over the same period. Landings of groundfish (excluding hake) were consistently at historically low levels over the last five years, while landings of crab and salmon varied within historical levels. Landings of shrimp increased to historically high levels and landings of highly migratory species have remained at historically high levels over the last five years.

Landings of recreational catch were consistently within historical averages over the last five years. The anomalously large recreational catch in 2002 is possibly a data error in Pacific halibut landings, and should be viewed with caution.

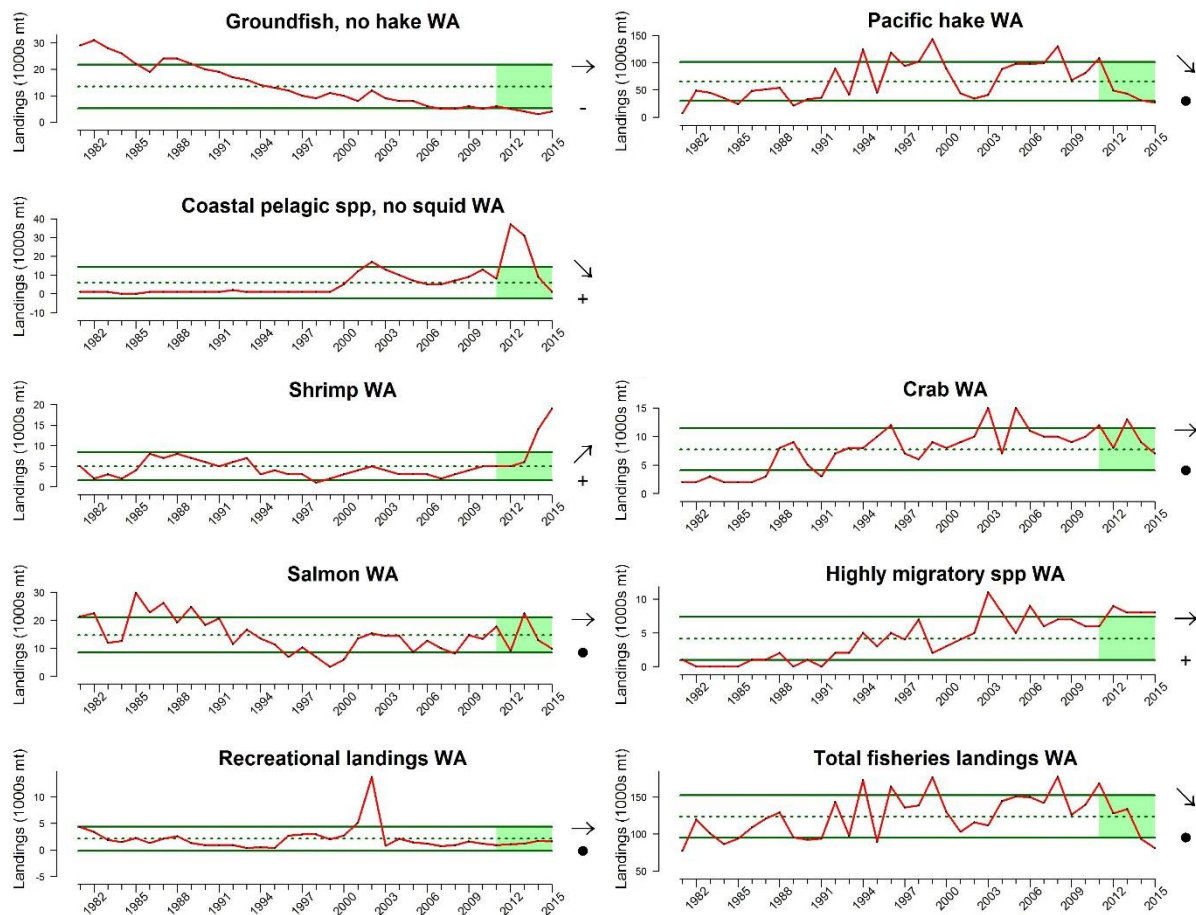


Figure K.3. Annual landings of commercial (data from PacFIN and NORPAC) and recreational fisheries (data from RecFIN), including total landings across all fisheries from 1981-2015 in Washington (WA). Lines and symbols are as in Figure 1.1a.

## K.2. RECREATIONAL TAKE BY STATE AND FMP

We further broke down the available RecFIN data on state-by-state recreational take (landings plus dead discard) from 1980-2015, and summarized them by how the species group under the FMPs. California was the location of the clear majority of recreational take in all species groupings except for salmon (Fig. K.4). Recreational take of CPS and groundfish has declined long-term, although

groundfish take has increased since 2008. Recreational HMS take has been highly variable; most recently, it rose sharply from 2011-2015, and the data imply that proportions of total recreational HMS caught in Oregon and Washington have increased since 2005. Recreational catch of salmon has also been highly variable at both the scale of the entire coast and among individual states. Peaks in recreational take in all states occurred in the late 1990s and early 2000s; since then, recreational salmon take has declined, particularly in California.

Recreational take of “other” species that do not fall directly under an FMP is dominated by California (Fig. K.4). Key species include California and Pacific halibut, barred sand bass, kelp bass, barracuda, yellowtail and surfperches. Take of these “other” species declined steeply between 2003 and 2010, but has been increasing slightly since then.

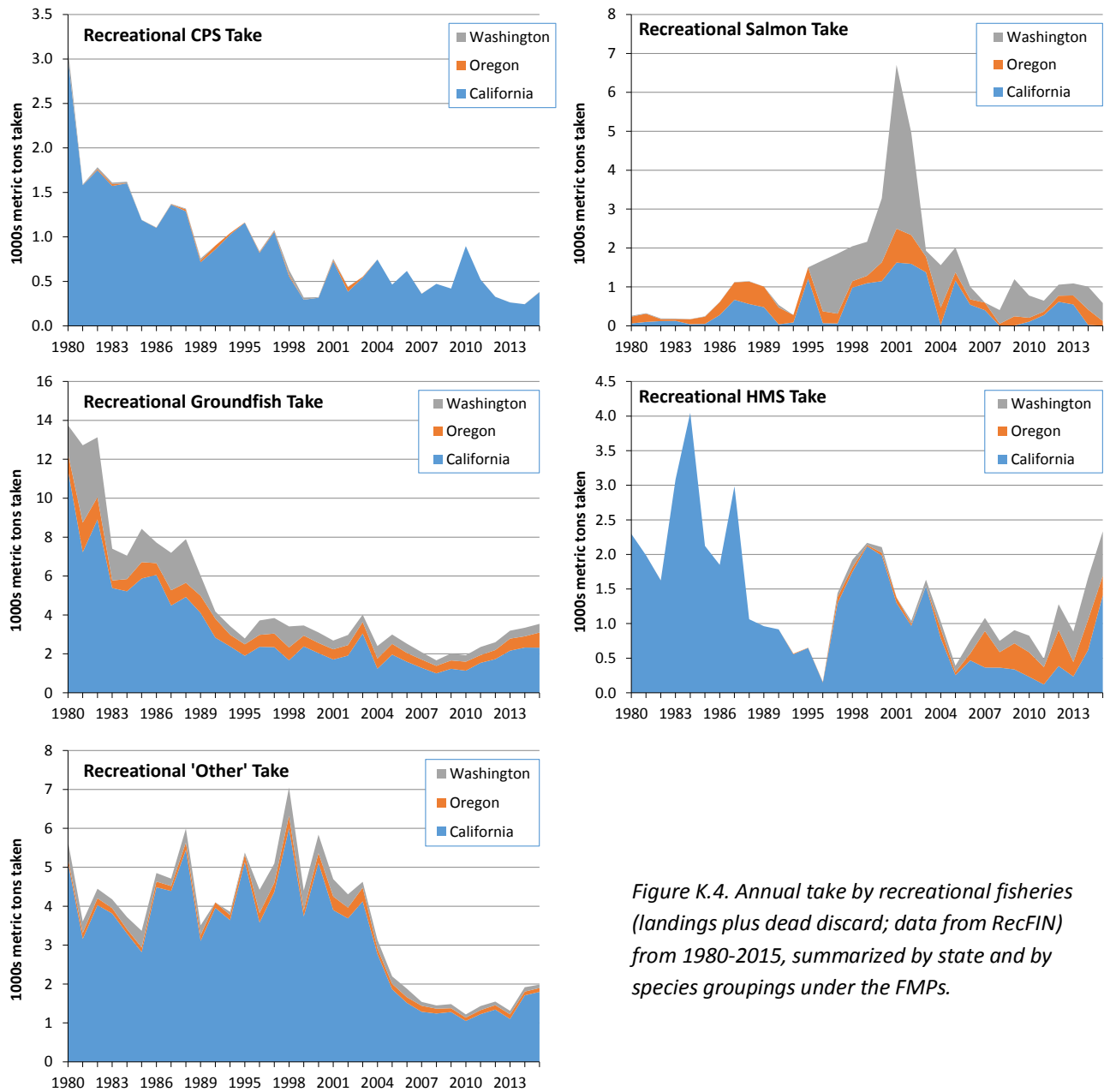


Figure K.4. Annual take by recreational fisheries (landings plus dead discard; data from RecFIN) from 1980-2015, summarized by state and by species groupings under the FMPs.

### K.3. COMMERCIAL FISHERY REVENUES

Total revenue across U.S. West Coast commercial fisheries decreased from 2011–2015, primarily due to large decreases in 2015 (Fig. K.5). This pattern was driven by decreases in crab, market squid and Pacific hake revenue over the last five years and, in particular, in 2015. The only fishery that increased revenue over the last five years was shrimp. Revenue of groundfish (excluding hake) remained consistently near historically low levels from 2011–2015, while revenue from salmon, highly migratory species and other species were relatively unchanged and within historical averages over the last five years.

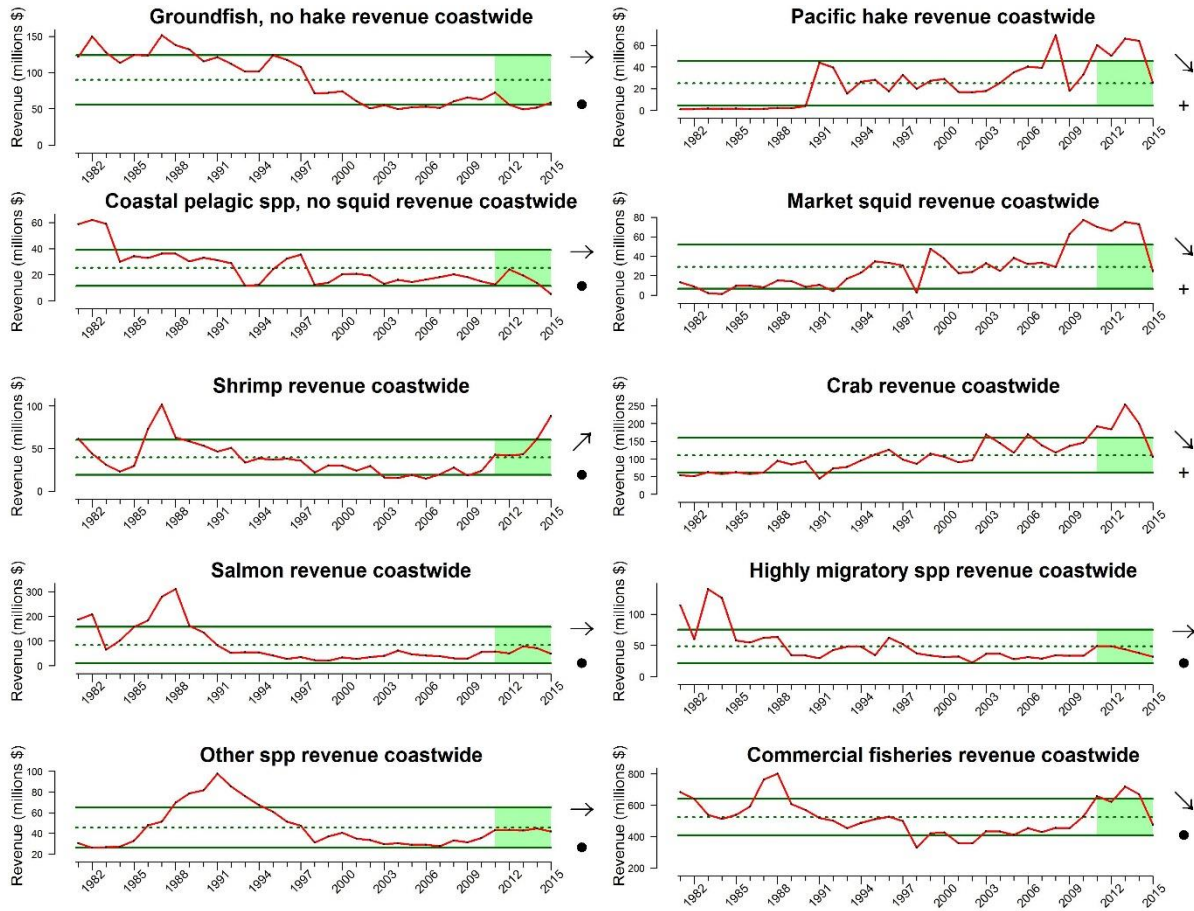


Figure K.5. Annual revenue (Ex-vessel value in 2015 dollars) of West Coast commercial fisheries (data from PacFIN) from 1981 - 2015, including at-sea hake revenue (data from the North Pacific Database Program (NORPAC)) from 1990–2015. Lines and symbols are as in Figure 1.1a.

Total revenue across commercial fisheries in California decreased from 2011–2015, primarily due to large decreases in 2015 (Fig. K.6). This pattern was driven by decreases in crab and market squid in 2015. The only fishery that increased revenue over the last five years was shrimp. Revenue of groundfish (excluding hake) and highly migratory species remained consistently near historically low levels from 2011–2015, while revenue from Pacific hake, salmon and other species were relatively unchanged and within historical averages over the last five years.

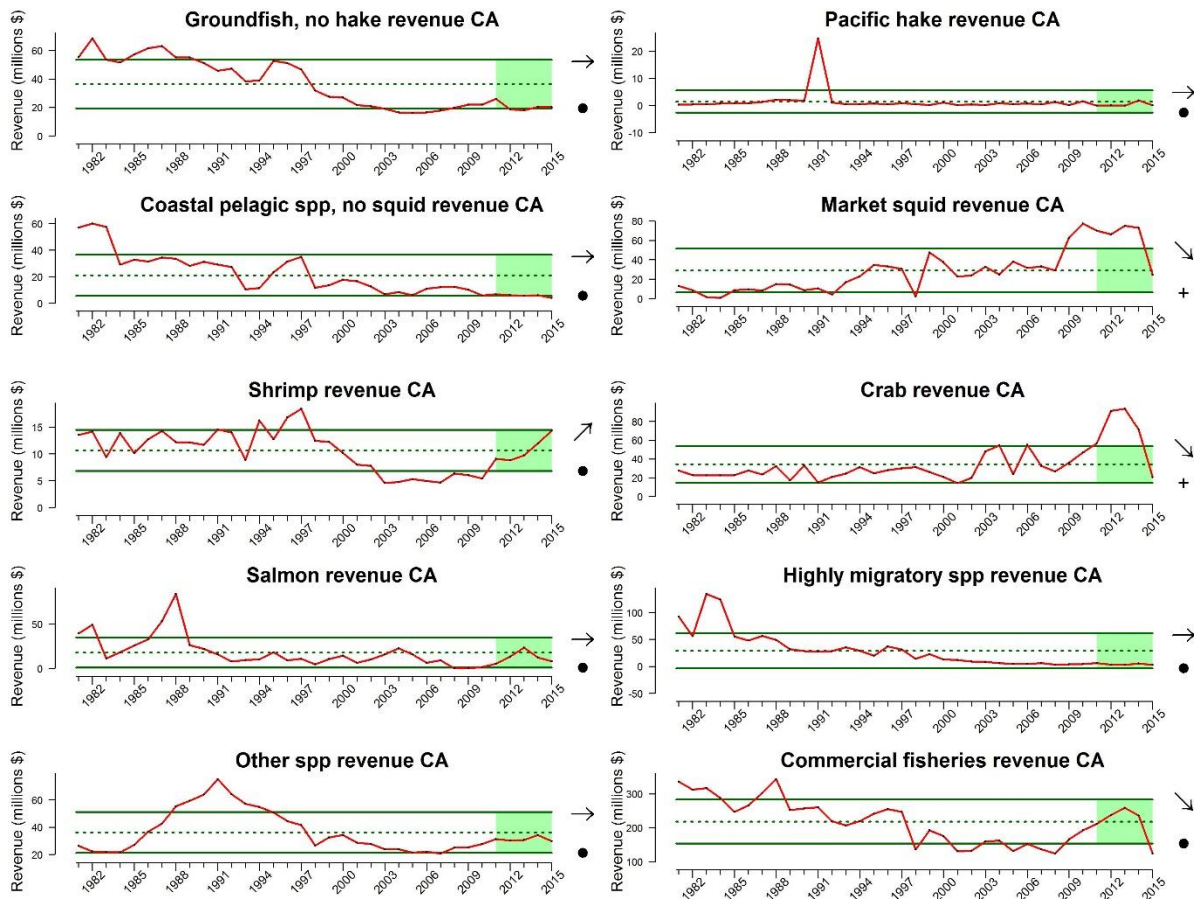


Figure K.6. Annual revenue (Ex-vessel value in 2015 dollars) of West Coast commercial fisheries (data from PacFIN) from 1981 - 2015, including at-sea hake revenue (data from the North Pacific Database Program (NORPAC)) from 1990–2015 in California (CA). Lines and symbols are as in Figure 1.1a.

Total revenue across commercial fisheries in Oregon was at historically high levels from 2011–2015 despite a large decrease in 2015 (Fig. K.7). This pattern was driven by decreases in Pacific hake and crab revenue in 2015. The only fishery that increased revenue over the last five years was shrimp. Revenue of groundfish (excluding hake) remained consistently near historically low levels from 2011-2015, while revenue from salmon and other species were relatively unchanged and within historical averages over the last five years. Revenue from highly migratory species has decreased gradually over the last five years.

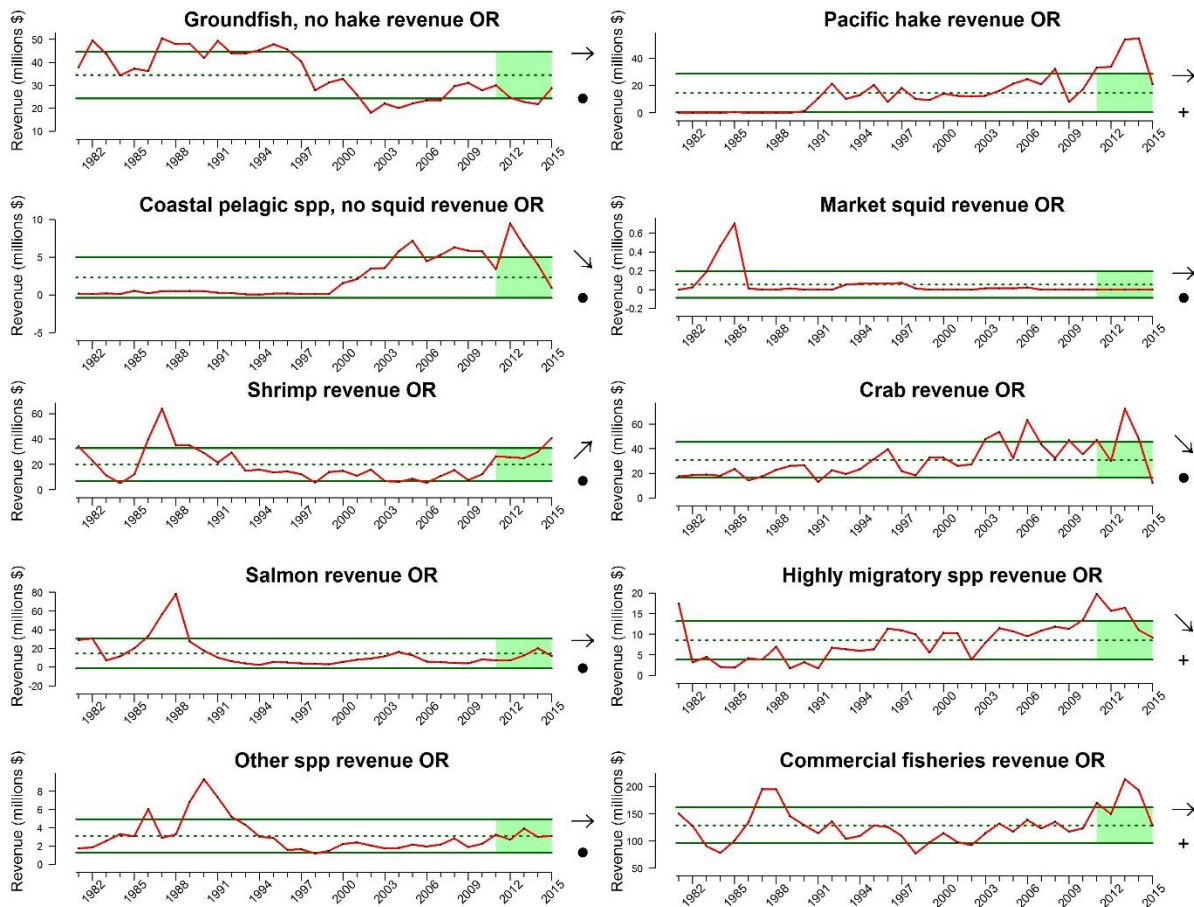


Figure K.7. Annual revenue (Ex-vessel value in 2015 dollars) of West Coast commercial fisheries (data from PacFIN) from 1981 - 2015, including at-sea hake revenue (data from the North Pacific Database Program (NORPAC)) from 1990-2015 in Oregon (OR). Lines and symbols are as in Figure 1.1a.

Total revenue across commercial fisheries in Washington remained relatively unchanged and at historically high levels from 2011–2015 (Fig. K.8). This is in sharp contrast with the decreases in revenue observed across the entire coast and in California and Oregon in 2015. Decreases in revenue in the Pacific hake and coastal pelagic species fisheries were offset by increases in revenue in the shrimp fishery in Washington over the last five years. Revenue of groundfish (excluding hake) remained consistently near historically low levels from 2011–2015, while revenue from salmon and other species were relatively unchanged and within historical averages over the period. Revenue from highly migratory species remained unchanged and at historically high levels over the last five years.

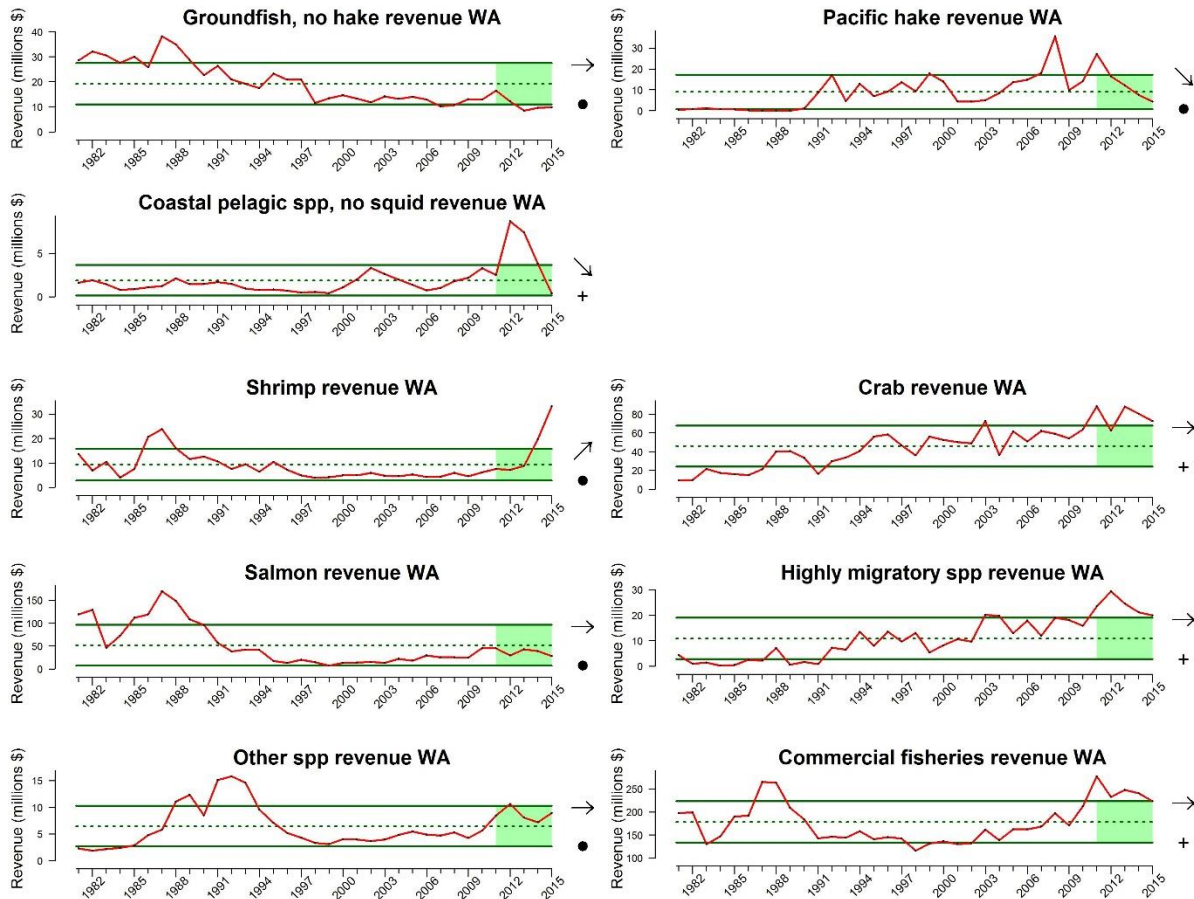


Figure K.8. Annual revenue (Ex-vessel value in 2015 dollars) of West Coast commercial fisheries (data from PacFIN) from 1981 - 2015, including at-sea hake revenue (data from the North Pacific Database Program (NORPAC)) from 1990-2015 in Washington (WA). Lines and symbols are as in Figure 1.1a.

## **APPENDIX L. FISHING GEAR CONTACT WITH SEAFLOOR HABITAT**

In Section 5.2 of the main body of this report, we presented the summary information for all distances (weighted) of fishing gear contact with seafloor habitat. Here, we present the data broken out by ecoregions (“Northern”: north of Cape Mendocino; “Central”: between Cape Mendocino and Point Conception; and “Southern”: south of Point Conception); substrate types (hard, mixed, soft); and depth zones (shelf, upper slope, lower slope).

Benthic marine habitats can be disturbed or destroyed by geological (e.g., earthquakes, fractures and slumping) and oceanographic (e.g., internal waves, sedimentation and currents) processes as well as various human activities (e.g., bottom contact fishing, mining, dredging), which can lead to declines or extirpation of vulnerable benthic species and disruption of food web processes. These effects may differ among physiographic types of habitat (e.g., hard, mixed or soft) and be particularly dramatic in sensitive environments (e.g., seagrass meadows, algal beds and coral or sponge reefs). The exploration of resources (e.g., oil, gas and minerals) and marine fisheries often tend to operate within certain habitat types more than others, and long-term impacts of these activities may cause negative changes in biomass and the production of benthic communities.

We used estimates of coastwide distances trawled along the ocean bottom from 1999 – 2015. Estimates from 2002 – 2015 include estimates of gear contact with seafloor habitat by bottom trawl and fixed fishing gear, while estimates from 1999 – 2002 include only bottom trawl data. We calculated trawling distances based on set and haul-back locations and fixed gear distances based on set and retrieval locations of pot, trap and longline gear. We weighted distances by gear type and fishing habitat according to sensitivity values described in Table A3a.2 of the 2013 Groundfish EFH Synthesis Report to PFMC. Data come from logbook data collected and reported by the Northwest Fisheries Science Center’s West Coast Groundfish Observer Program.

At the scale of the entire U.S. West Coast, gear contact with seafloor habitat remained at historically low levels from 2011–2015 (Fig. L.1). During this period, the vast majority of fishing gear contact with seafloor habitat occurred in soft-bottomed habitats on the upper slope and shelf. Moreover, the vast majority of this contact was by bottom trawl gear (data by gear type not shown). The Northern ecoregion experienced the most fishing gear contact with seafloor habitat, with nearly four times the magnitude as observed in the Central ecoregion and >40 times the magnitude observed in the Southern ecoregion, where very little bottom trawling has occurred within the time series. A shift in trawling effort from shelf to upper slope habitats was observed during the mid-2000’s, which in part corresponded to depth-related spatial closures implemented by the Pacific Fishery Management Council. When compared to the mean for the entire time series, gear contact with seafloor habitats across all habitats has been within historic levels (statistics not shown due to space limitations). Reduced fishing gear contact may not coincide with recovery times of habitat depending on how fast recovery happens, which is likely to differ among habitat types (e.g., hard and mixed habitats will take longer to recover than soft habitat).



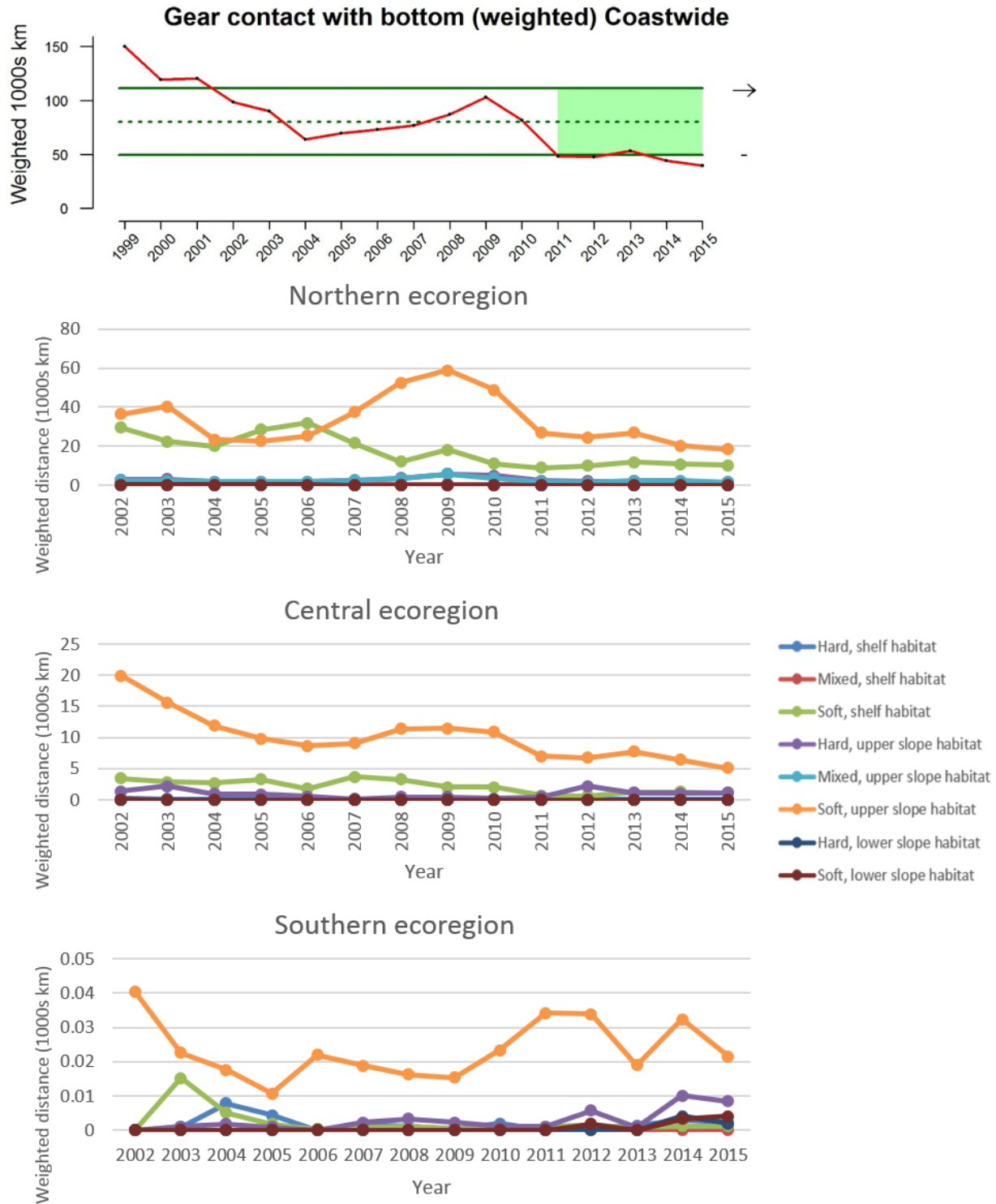


Figure L.1: Weighted distance (1000s km) of fishing gear contact with seafloor habitat across the entire CCE (top; 1999-2015) and within each ecoregion (bottom three panels; 2002-2015). Lines, colors and symbols in top panel are as in Fig. 1.1a.

## APPENDIX M. OTHER NON-FISHERIES HUMAN ACTIVITIES INDICATORS

Approximately 90% of world trade is carried by the international shipping industry. The volume of cargo moved through U.S. ports is expected to double between 2001 and 2020. Fisheries impacts associated with commercial shipping include interactions between fishing and shipping vessels; ship strikes of protected species; and underwater noise that affects fish spawning, recruitment, migration, and communication. Commercial shipping activity in the CCE was at historically low levels over the last five years of the dataset (through 2013; Fig. M.1). This contrasts with global estimates of shipping activity increasing nearly 400% over the last 20 years. Regional differences, lagging economic conditions and different data sources may be responsible for the observed differences.

Nutrient loading is a leading cause of contamination, eutrophication, and related impacts in streams, lakes, wetlands, estuaries, and ground water throughout the U.S. Nutrient input has been relatively constant and within historical averages over the last five years of the available dataset (2008–2012) (Fig. M.2). Applications of nitrogen and phosphorus increased steeply from 1945 until 1980, followed by a relatively sharp, stepped increase in the 2000's. However, a comparable decrease occurred in 2009, and loadings have remained within the long-term mean range through 2012.

Risks posed by offshore oil and gas activities include the release of hydrocarbons, smothering of benthos, sediment anoxia, benthic habitat loss, and the use of explosives. Petroleum products consist of thousands of chemical compounds, such as PAHs, which may impact marine fish health and reproduction. The effects of oil rigs on fish stocks are less conclusive, as rig structures may provide some habitat benefits. Offshore oil and gas activity in the CCE occurs only off the coast of California and has been stable over the last five years, but the short-term average was more than 1 s.d. below the long-term average (Fig. M.3). Offshore oil and gas production has been decreasing steadily since the mid 1990's.

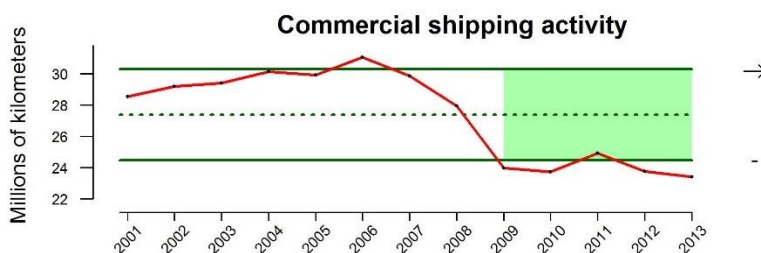


Figure M.1: Distance transited by commercial shipping vessels in the CCE, 2001-2013. Lines and symbols are as in Figure 1.1a.

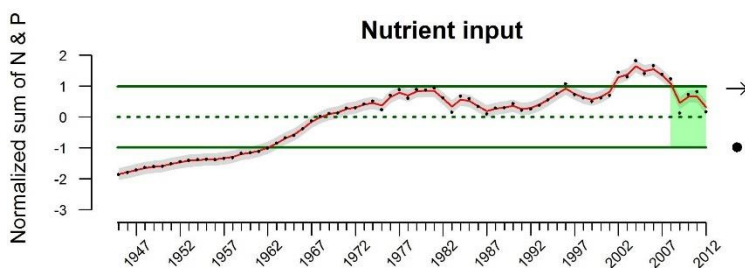


Figure M.2: Normalized index of the sum of nitrogen and phosphorus applied as fertilizers in WA, OR and CA watersheds that drain into the CCE from 1945-2012. Lines, symbols and shading are as in Figure 1.1a.

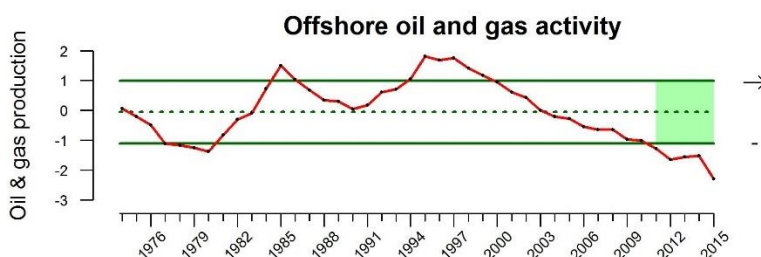


Figure M.3: Normalized index of the sum of oil and gas production from offshore wells in CA, 1974-2014. Lines and symbols are as in Figure 1.1a.

## APPENDIX N. SOCIAL VULNERABILITY OF COMMERCIAL FISHING-DEPENDENT COMMUNITIES

In Section 6.1 of the main report, we present information on the Community Social Vulnerability Index (CSVI) as an indicator of social vulnerability in coastal communities that are dependent upon commercial fishing in the CCE. Figure 6.1.1 presented CSVI and fishery dependence for all five regions of the CCE in the same radar plot; here, we separately present both indices for each region's ten most fishery-dependent coastal communities as of 2014. The community with the greatest commercial fishing dependency in each region is at the top of the radar plot, and other communities are plotted in clockwise descending order of fishery dependency.

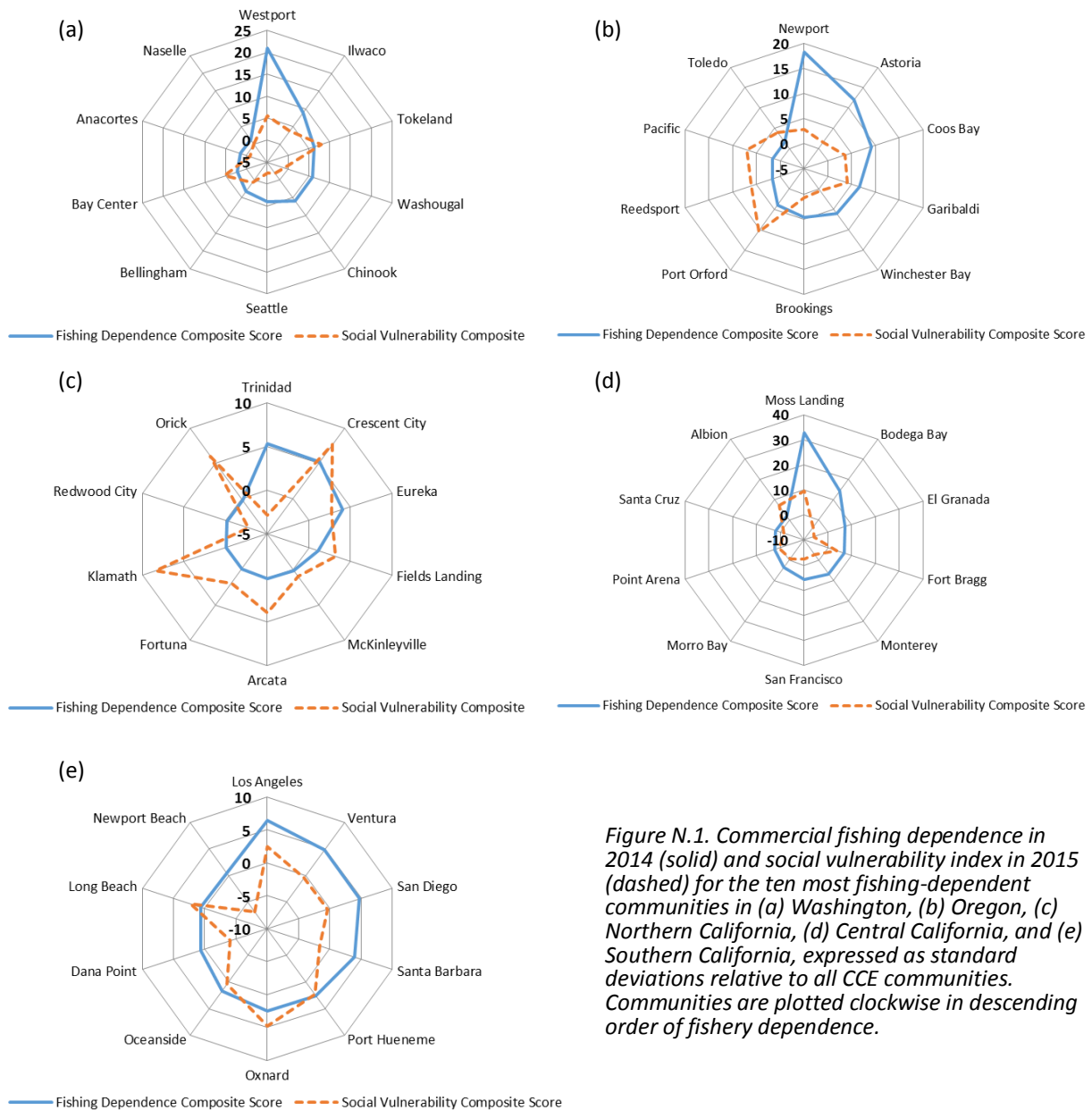


Figure N.1. Commercial fishing dependence in 2014 (solid) and social vulnerability index in 2015 (dashed) for the ten most fishing-dependent communities in (a) Washington, (b) Oregon, (c) Northern California, (d) Central California, and (e) Southern California, expressed as standard deviations relative to all CCE communities. Communities are plotted clockwise in descending order of fishery dependence.

In addition to the recent indices, we have now analyzed sufficient sociodemographic data from the U.S. Census and American Community Survey (ASC) of the type presented to augment a 2000-2015 time series of coastal community vulnerability in relation to commercial fishery dependence. This time series focuses on ten commercial fishing-dependent communities that consistently scored among the most socially vulnerable in all years. We plotted their CSVI composite scores for each year, and found for many communities, levels of community social vulnerability remained fairly stable over the time period examined (Fig. N.2). There were several exceptions. For example, Moss Landing, CA, experienced a steady increase in social vulnerability. Both Bay Center, WA and Tokeland, WA decreased in vulnerability from 2000 to 2005, but have seen increases since then. In contrast, Chinook, WA increased in vulnerability until 2010 but then declined sharply by 2015. Further research is needed to understand the factors causing the changes and volatility in these data.

Because this time series has only four data points, it remains difficult to interpret and subject to bias from influential data points. Furthermore, because our social vulnerability data presently underrepresents tribal communities and also may not aggregate or disaggregate certain communities in a properly representative manner, we urge caution in interpreting these results.

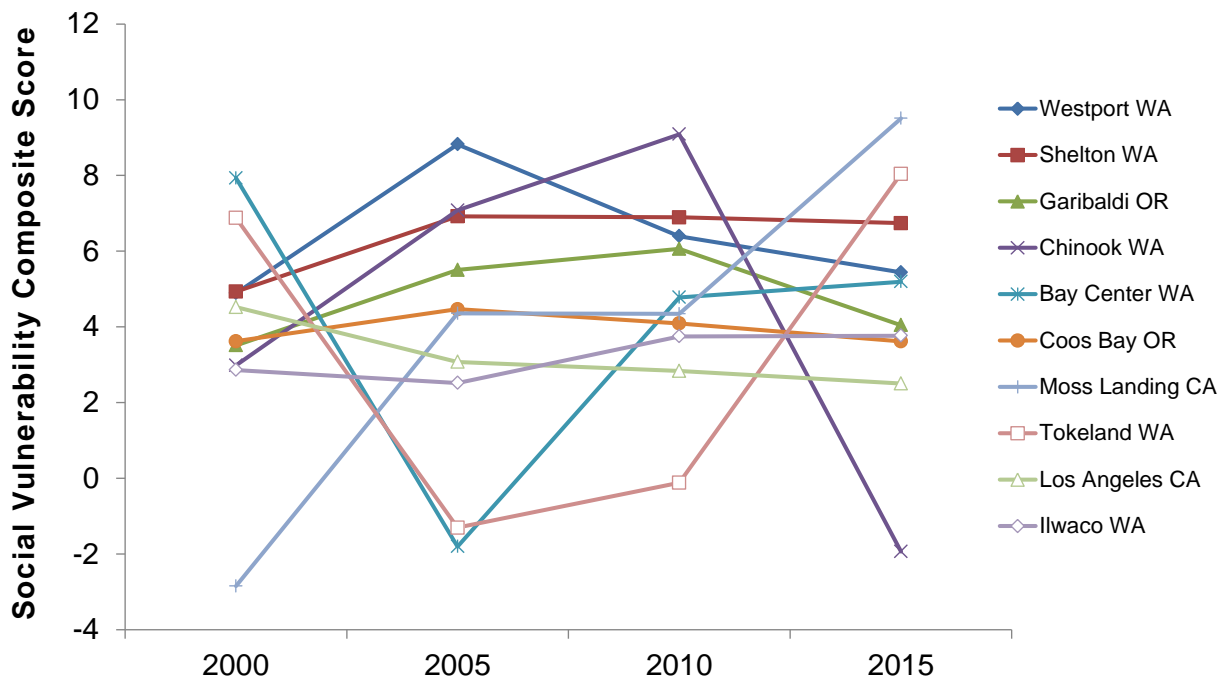


Figure N.2. Time series of social vulnerability composite scores (derived from census data in 2000, 2005, 2010, and 2015) for ten highly vulnerable coastal communities that are dependent upon commercial fishing.

## APPENDIX O. FLEET DIVERSIFICATION INDICATORS FOR MAJOR WEST COAST PORTS

As is true with individual vessels, the variability of landed value at the port level is reduced with greater diversification of landings. Diversification of fishing revenue has declined over the last several decades through 2015 for some ports (Fig. O.1). Examples include Seattle and most, though not all, of the ports in Southern Oregon and California. However, a few ports have become more diversified including Bellingham Bay and Westport in Washington and Astoria in Oregon. Diversification scores are highly variable year-to-year for some ports, particularly those in Southern Oregon and Northern California that depend heavily on the Dungeness crab fishery, which has highly variable landings. Several California ports have become more diversified in the last few years, but it is too early to determine whether this is a significant trend.

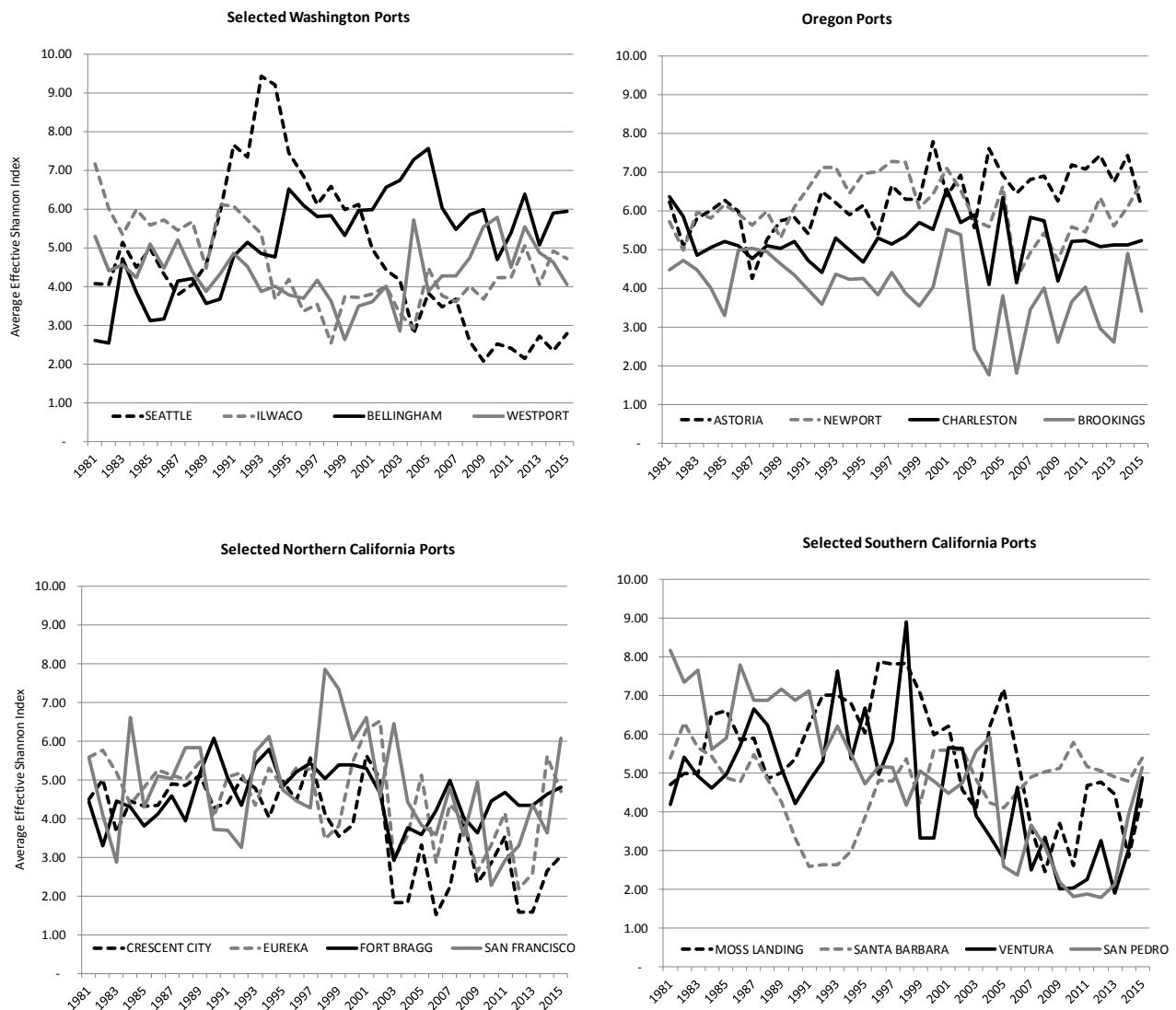


Figure O.1. Trends in diversification for selected major West Coast ports in Washington, Oregon, and California.

## APPENDIX P. REFERENCES

- Abell, R., *et al.* 2008. Freshwater ecoregions of the world: A new map of biogeographic units for freshwater biodiversity conservation. *BioScience* 58:403-414.
- Bond, N. A., M. F. Cronin, H. Freeland, and N. Mantua. 2015. Causes and impacts of the 2014 warm anomaly in the NE Pacific. *Geophysical Research Letters* 42:3414-3420.
- Burke, B. J., W. T. Peterson, B. R. Beckman, C. Morgan, E. A. Daly, and M. Litz. 2013. Multivariate models of adult Pacific salmon returns. *PLoS One* 8:e54134.
- Chan, F., J. A. Barth, J. Lubchenco, A. Kirincich, H. Weeks, W. T. Peterson, and B. A. Menge. 2008. Emergence of anoxia in the California current large marine ecosystem. *Science* 319:920-920.
- Colburn, L., M. Jepson, C. Weng, T. Seara, J. Weiss, and J. Hare. 2016. Indicators of climate change and social vulnerability in fishing dependent communities along the Eastern and Gulf Coasts of the United States. *Marine Policy* (in press).
- Feely, R. A., C. L. Sabine, J. M. Hernandez-Ayon, D. Ianson, and B. Hales. 2008. Evidence for upwelling of corrosive "acidified" water onto the continental shelf. *Science* 320:1490-1492.
- Fisher, J. L., W. T. Peterson, and R. R. Rykaczewski. 2015. The impact of El Niño events on the pelagic food chain in the northern California Current. *Global Change Biology* 21:4401-4414.
- Kaplan, I. C., and K. N. Marshall. 2016. A guinea pig's tale: learning to review end-to-end marine ecosystem models for management applications. *ICES Journal of Marine Science* 73:1715-1724.
- Kasperski, S., and D. S. Holland. 2013. Income diversification and risk for fishermen. *Proceedings of the National Academy of Sciences of the United States of America* 110:2076-2081.
- Keister, J. E., E. Di Lorenzo, C. A. Morgan, V. Combes, and W. T. Peterson. 2011. Zooplankton species composition is linked to ocean transport in the Northern California Current. *Global Change Biology* 17:2498-2511.
- Leising, A. W., *et al.* 2015. State of the California Current 2014-15: Impacts of the Warm-Water "Blob". *CalCOFI Reports* 56:31-68.
- Lewis, R. L., *et al.* 2015. Dynamic Ocean Management: Identifying the Critical Ingredients of Dynamic Approaches to Ocean Resource Management. *BioScience* 65:486-498.
- McClatchie, *et al.* 2016. State of the California Current 2015-16: comparisons with the 1997-98 El Niño. *CalCOFI Reports* 57:5-61.
- Peterson, W. T., J. L. Fisher, J. O. Peterson, C. A. Morgan, B. J. Burke, and K. L. Fresh. 2014. Applied fisheries oceanography ecosystem indicators of ocean condition inform fisheries management in the California Current. *Oceanography* 27:80-89.
- Reynolds, R.W., T. M. Smith, C. Liu, D. B. Chelton, K. S. Casey, and M. G. Schlax, 2007. Daily high-resolution-blended analyses for sea surface temperature. *Journal of Climate* 20:5473-5496.
- Santora, J. A., I. D. Schroeder, J. C. Field, B. K. Wells, and W. J. Sydeman. 2014. Spatio-temporal dynamics of ocean conditions and forage taxa reveal regional structuring of seabird-prey relationships. *Ecological Applications* 24:1730-1747.
- Wells, B.K., J.A. Santora, I.D. Schroeder, W.J. Sydeman, D.D. Huff, and J.C. Field. 2016. Marine ecosystem perspectives on Chinook salmon recruitment: a synthesis of empirical and modeling studies from the California upwelling system. *Marine Ecology Progress Series* 552:271-284.

## APPENDIX Q. LIST OF ACRONYMS USED IN THIS REPORT

BMSY	Biomass when at Maximum Sustainable Yield
CalCOFI	California Cooperative Oceanic Fisheries Investigations
CCE	California Current Ecosystem
CCIEA	California Current Integrated Ecosystem Assessment
CPS	Coastal Pelagic Species
CPUE	Catch per Unit Effort
CSVI	Community Social Vulnerability Index
CUI	Cumulative Upwelling Index
DO	Dissolved Oxygen
DOM	Dynamic Ocean Management
EBFM	Ecosystem-Based Fisheries Management
ENSO	El Niño Southern Oscillation
ESI	Effective Shannon Index
EWG	Ecosystem Working Group (resulting from FEP Coordinated Ecosystem Indicator Review Initiative)
FEP	Fishery Ecosystem Plan
FMP	Fishery Management Plan
FMSY	Fishing mortality rate that produces Maximum Sustainable Yield
IEA	Integrated Ecosystem Assessment
MARSS	Multivariate Auto-Regressive State Space model
NOAA	National Oceanic and Atmospheric Administration
NPGO	North Pacific Gyre Oscillation
NWFSC	Northwest Fisheries Science Center
OA	Ocean Acidification
OFL	Overfishing Limit
ONI	Oceanic Niño Index
PacFIN	Pacific Fisheries Information Network
PDO	Pacific Decadal Oscillation
PFMC	Pacific Fishery Management Council
POP	Pacific Ocean Perch
RecFIN	Recreational Fisheries Information Network
s.d.	standard deviation
s.e.	standard error
SSC	Scientific and Statistical Committee
SSCES	Scientific and Statistical Committee Ecosystem Subcommittee
SST	Sea Surface Temperature (except Fig. 4.4.1, shortspine thornyhead)
SSTa	Sea Surface Temperature anomaly
SWE	Snow-Water Equivalent
SWFSC	Southwest Fisheries Science Center
UI	Bakun Upwelling Index
YOY	Young-of-the-Year